MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XL. DECEMBER 12, 1879. No. 2.

LORD LINDSAY, M.P., F.R.S., President, in the Chair.

Observations of the Solar Eclipse 1879, *July* 18, *made at the University Observatory, Strasburg.* By Prof. A. Winnecke.

The morning of July 19 was extremely cloudy. Different observers with smaller telescopes got neither the beginning nor the end of the eclipse. I was myself a little more fortunate. The Refractor by Merz which I used has an aperture of 101^{mm}; and a polarisation eye-piece, power 105, was applied. At $3^h\ 50^m\ 15^s$ Strasburg sidereal time, clouds left the Sun; the eclipse had just commenced.

The end was, between thick clouds, very uncertainly observed at $4^h\ 27^m\ 50^s{\cdot}5$ Strasburg sidereal time.

From this account it is clear that, in the ordinary way of observing a partial solar eclipse, this one would have been nearly lost for Strasburg; but fortunately we have taken measures with the Heliometer. I had asked Herr Hartwig, Assistant of the Observatory, to profit by every bit of clear sky; he was aided by Dr. Küstner, who read the microscopes of the scales and of the position-circle.

Herr Hartwig obtained seven measures of the length of the chord joining the cusps, and seven angles of position of it; the power of the eye-piece was 170.

Diminishing the *Nautical Almanac* R.A. of the Moon by $10''{\cdot}0$ and correcting by $-1''{\cdot}90$ the *Nautical Almanac* semi-diameter of the Sun, and by $-2''{\cdot}30$ the *Nautical Almanac* semi-

diameter of the Moon (see *Monthly Notices*, vol. xxxvi., p. 86), Herr Hartwig obtained the equations:

Measures of length of chord connecting the cusps.

$$
\begin{aligned}
0 &= -23''09 + 4''016\,dr + 4''019\,d\mathrm{R} + 1''132\,dx + 3''722\,dy + i.\\
0 &= -18''88 + 4''037\,dr + 4''090\,d\mathrm{R} + 0''684\,dx + 3''853\,dy + i.\\
0 &= -18''59 + 4''263\,dr + 4''266\,d\mathrm{R} + 0''566\,dx + 4''106\,dy - i.\\
0 &= -25''44 + 4''570\,dr + 4''573\,d\mathrm{R} + 0''476\,dx + 4''435\,dy - i.\\
0 &= -28''39 + 5''046\,dr + 5''047\,d\mathrm{R} + 0''384\,dx + 4''930\,dy - i.\\
0 &= -28''17 + 6''026\,dr + 6''015\,d\mathrm{R} + 0''270\,dx + 5''924\,dy - i.\\
0 &= -31''90 + 7''605\,dr + 7''605\,d\mathrm{R} + 0''164\,dx + 7''537\,dy + i.
\end{aligned}
$$

Measures of angle of position of the chords.

$$
\begin{aligned}
0 &= +3''10 - 0''246\,dx + 0''075\,dy + \gamma - \delta.\\
0 &= -4''99 - 0''252\,dx + 0''045\,dy + \gamma + \delta.\\
0 &= -3''66 - 0''239\,dx + 0''033\,dy - \gamma + \delta.\\
0 &= +4''08 - 0''214\,dx + 0''020\,dy - \gamma - \delta.\\
0 &= +5''59 - 0''210\,dx + 0''016\,dy - \gamma - \delta.\\
0 &= -3''62 - 0''168\,dx + 0''008\,dy - \gamma + \delta.\\
0 &= +4''19 - 0''133\,dx + 0''003\,dy + \gamma - \delta.
\end{aligned}
$$

In these equations the symbols denote:

dr = Correction to the adopted semi-diameter of the Sun.

$d\mathrm{R}$ = ,, ,, ,, Moon.

dx = ,, ,, excess of Moon's R.A. over Sun's R.A.

dy = ,, to excess of Moon's Decl. over Sun's Decl.

i = ,, of adopted point of coincidence of images.

γ = Distance of optical centres of the halves of the object-glass.

δ = Error committed by the observer in rotating the object-glass in arc of great circle.

By treating the fourteen equations according to the method of least squares, Herr Hartwig obtained the final equations:

$$
\begin{aligned}
2''857\,dx + 15''968\,dy + 0''284\,i + 0''191\,\gamma + 0''135\,\delta - 86''073 &= 0.\\
15''968\,dx + 181''442\,dy - 4''283\,i + 0''046\,\gamma - 0''028\,\delta - 895''069 &= 0.\\
0''284\,dx - 4''283\,dy + 7''000\,i + 0''000\,\gamma + 0''000\,\delta + 26''720 &= 0.\\
0''191\,dx + 0''046\,dy + 0''000\,i + 7''000\,\gamma - 1''000\,\delta - 0''390 &= 0.\\
0''135\,dx - 0''028\,dy + 0''000\,i - 1''000\,\gamma + 7''000\,\delta - 28''930 &= 0.
\end{aligned}
$$

Hence :

$$
\begin{aligned}
dx &= +5''\cdot173 - 0''\cdot224\, dr - 0''\cdot229\, dR. \\
dy &= +4''\cdot448 - 1''\cdot006\, dr - 1''\cdot006\, dR. \\
i &= -1''\cdot306 + 0''\cdot000\, dr - 0''\cdot001\, dR. \\
\gamma &= +0''\cdot474 + 0''\cdot013\, dr + 0''\cdot013\, dR. \\
\delta &= +4''\cdot119 + 0''\cdot002\, dr + 0''\cdot002\, dR.
\end{aligned}
$$

The probable error of an observation is $1''\cdot48$; it would have been sensibly smaller had there not been so many clouds, which are very dangerous for double-image measures. Nevertheless, the position of the Moon is rigidly determined.

Taking the *Nautical Almanac* R.A. of the Sun as correct, we have :—

Correction to Moon's R.A.	$-4''\cdot47 - 0''\cdot224\, dr - 0''\cdot229\, dR$	$\pm 1''\cdot26$ prob. error.
Correction to Moon's Decl.	$+4''\cdot45 - 1''\cdot006\, dr - 1''\cdot006\, dR$	$\pm 0''\cdot16$ „

With these corrections and the values of the diameters adopted in the former calculations, the end of the eclipse is $4^h\ 28^m\ 19^s\cdot5$ Strasburg sidereal time. I thus lost the Moon very early ; but it must be remembered that the rate of separation of the limb of the Sun and the Moon is extremely slow, the distance of the centres changing about $1''$ of arc in every 10^s of time.

Strasburg, 1879, *Nov.* 5.

On the Polarisation of the Solar Corona.

By Arthur Schuster, Ph.D., F.R.S.

1.—Introductory.

Accurate measurements of the polarisation of the light sent out by the solar corona will most likely give us some important information on the nature of the Sun's surroundings. It is therefore a matter of interest to calculate the polarisation due to the scattering of light by a particle placed in the neighbourhood of a luminous sphere.

Before we can apply the theoretical results to the actual phenomenon, we must take account of all the particles along one given line of sight. We cannot do this, as we do not know the law of distribution of the scattering particles round the luminous sphere. We are therefore obliged to discuss various possible laws, and to see how the theoretical results agree with observed facts. A further complication is introduced by a large and unknown quantity of unpolarised light mixed up with the corona and most likely due to incandescence. Our problem is an inverse one, and seems at first sight very hopeless. From the observed polarisation of light we are to find out what part of it is due to

scattering particles, and, as will be seen, we cannot do this without finding out at the same time in what way the scattering particles are distributed round the Sun and in what way the light due to other causes varies with the distance from the Sun. I began the calculation in the hope of getting a rough idea only of the amount of polarisation which we might expect. But it appeared that even such observations as we can make during the short time available during a total solar eclipse may yield most important information as to the constitution of the solar corona. I shall show that combined measurements of the polarisation at different distances from the Sun and of the decrease in intensity of the total light of the corona with increasing distance from the Sun will be sufficient to determine all our unknown quantities. Even if such measurements are incomplete, we may gain a rough idea of these quantities, and even a solitary observation like that of Mr. Winter during the eclipse of 1871 will give some results. We may hope to obtain, by means of the polariscope, answers to the following questions:—

In what way is the scattering matter distributed in the solar atmosphere?

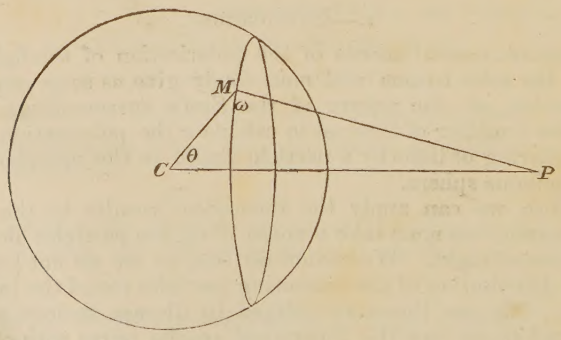
What part of the light sent out by the corona is due to scattering matter?

Is the scattering matter projected outwards from the Sun, or is it falling into the Sun from outside?

2.—Light emanating from a Luminous Sphere is scattered by a Small Particle.

I shall begin by calculating the phenomena of polarisation shown by a single scattering particle when placed at different distances from the Sun.

Fig. 1.



In the figure let

C = centre of luminous sphere.

M = any point on the surface of the sphere.

P = position of scattering particle.

Also adopt the following notation :—

O = position of observer's eye.
PM = y.
PC = r.
ω = angle PMC.
θ = „ MCP.
ϕ = „ between planes MCP and CPO.
χ = „ CPO.
η = „ between planes CPO and MPO.
α = „ MPO.

We fix our unit of length to be the radius of the luminous sphere.

We have to resolve the light sent out by the element of surface at M and scattered at P into two components, one polarised in the plane MPO and the other at right angles to that plane. Let B^2 be the intensity of that component of the scattered ray which is polarised in the plane MPO; then $B^2 \cos^2 \alpha$ will be the component which is polarised at right angles to that plane.* The intensity resolved in any plane forming an angle δ with MPO will be

$$B^2 (\cos^2 \delta + \cos^2 \alpha \sin^2 \delta).$$

We shall refer the polarisation, however, not to the plane MPO, which varies with the position of M, but to the plane CPO, which forms an angle η with MPO. Putting $\epsilon = \delta - \eta$, we find the component polarised in a plane forming an angle ϵ with the radial plane

$$B^2 \cos^2 (\eta + \epsilon) + \sin^2 (\eta + \epsilon) \cos^2 \alpha = B^2 S, \quad (1)$$

where

$$S = 1 - \sin^2 \alpha \sin^2 (\eta + \epsilon). \quad (2)$$

In the spherical triangle formed at P by the lines PC, PM, PO we have

$$\sin \alpha \sin \eta = \sin \omega \sin \phi, \quad (3)$$

$$\sin \alpha \cos \eta = \cos \omega \sin \chi - \sin \omega \cos \chi \cos \phi, \quad (4)$$

or

$$\sin^2 \alpha \sin^2 (\eta + \epsilon) = \sin^2 \phi \cos^2 \epsilon \sin^2 \omega + \sin^2 \epsilon \cos^2 \omega \sin^2 \chi + \cos^2 \phi \sin^2 \epsilon \sin^2 \omega \cos^2 \chi + X, \quad (5)$$

* *See* a Paper by Lord Rayleigh, "On the Light from the Sky; its Polarisation and Colour," *Phil. Mag.*, 1871, vol. xli., p. 107.

where X consists of three terms involving ϕ only in the form $\sin\phi$, $\cos\phi$, $\sin\phi\cos\phi$ respectively. These terms will disappear in any integration with respect to ϕ between the limits 0 and 2π.

If I represents the light sent out normally by the luminous sphere, the intensity of the light falling on the point P from an element of surface at M will be $Id\Omega$, where $d\Omega$ is the solid angle subtended at P by the element of surface dS. Instead of integrating over the luminous sphere, we can integrate over the unit sphere surrounding P. We have

$$d\Omega = \sin\omega\, d\omega\, d\phi = -d\phi\, d\cos\omega.$$

The intensity of the light scattered by P will therefore be

$$B^2 I \int_{\cos\omega_1}^{1} \int_0^{2\pi} S\, d\cos\omega\, d\phi,$$

where ω_1 is the angle between CP and the tangent to the sphere from P. But

$$\frac{1}{\pi}\int_0^{2\pi} S\, d\phi = (1+\sin^2\epsilon\sin^2\chi)+\cos^2\omega\,(1-3\sin^2\epsilon\sin^2\chi).$$

Integrating this with respect to $\cos\omega$, between the proper limits, and writing again ω for ω_1, we find for the intensity of vibration resolved in any direction determined by ϵ

$$\frac{IB^2}{\pi}\left[\left(\frac{4}{3}-\cos\omega-\frac{\cos^3\omega}{3}\right)-\sin^2\epsilon\sin^2\chi\,(\cos\omega-\cos^3\omega)\right]. \qquad (6)$$

Fixing our unit of intensity so that $\frac{B^2 I}{\pi} = \frac{1}{2}$, we have for the light polarised in the radial plane ($\epsilon = 0$)

$$2g_0 = \frac{1}{3}(1-\cos\omega)(4+\cos\omega+\cos^2\omega), \qquad (7)$$

and for the light polarised in a perpendicular plane ($\epsilon = \frac{1}{2}\pi$)

$$2g_1 = 2g_0 - \sin^2\chi\,(1-\cos\omega)(\cos\omega+\cos^2\omega). \qquad (8)$$

It is usual in polariscopic measurements to express the degree of polarisation p by the ratio of the polarised to the total light, which in our notation would be

$$p = \frac{g_0-g_1}{g_0+g_1}.$$

We shall find it more convenient to express the polarisation by the ratio of the polarised light to the stronger component, or by

$$q = \frac{g_0 - g_1}{g_0}.$$

Between q and p we have the relation

$$\frac{1}{p} = \frac{2}{q} - 1,$$

which shows that the two quantities will always increase and decrease together. We find, therefore, for the light scattered by a particle,

$$q = 3 \sin^2 \chi \frac{\cos \omega + \cos^2 \omega}{4 + \cos \omega + \cos^2 \omega}. \qquad (9)$$

For a given value of χ this quantity evidently increases with decreasing ω, or with increasing distance from the Sun. The fraction is always positive, and therefore the polarisation is always radial.

If the scattering particle is situated close to the surface of the Sun, $\cos \omega = 0$ and

$$g_0 = g_1.$$

Hence the light is altogether unpolarised. If the point is at an infinite distance from the sphere, $\cos \omega = 1$ and

$$\frac{g_0 - g_1}{g_0} = \sin^2 \chi;$$

that is to say, the luminous sphere behaves like a luminous point, as is evident *à priori*.

We can put (6) under the form

$$\frac{1}{3}(2 - 3 \cos \omega + \cos^3 \omega) + \frac{1}{2}(1 - \sin^2 \epsilon \sin^2 \chi) \cos \omega \sin^2 \omega. \qquad (10)$$

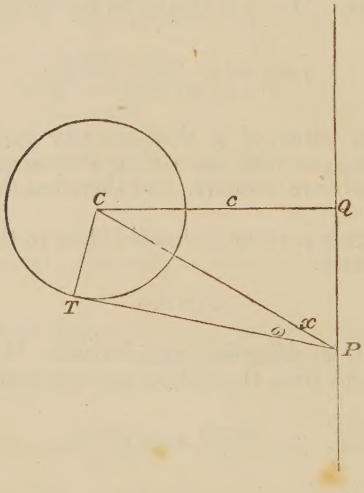
As $\sin^2 \omega = \frac{1}{r^2}$, the second term represents light which would be scattered by the particle if the luminous sphere were replaced by a point placed at its centre and sending out light of an intensity $\frac{\cos \omega}{2B^2}$. The first term represents light which is altogether unpolarised and which might therefore be due to the self-luminosity of the particles.

This way of expressing the scattered light shows well how, on the one hand, at an infinite distance the sphere can altogether be replaced by a luminous point; while, on the other hand the

polarised part disappears altogether if the particle is in contact with the Sun.

Let us now consider in what way the polarisation of the scattered light changes as the scattering particle is moved along a line of sight. Consider the line of sight, for instance, to be the tangent to the luminous sphere. Close to the Sun, as I have shown, the light is entirely unpolarised. As the particle is moved either way along the tangent, the polarisation increases. At large distances it must vanish again, and hence it must pass a maximum. We shall investigate the position of this maximum.

Fig. 2.



Let QP be a line of sight, P being the position of the particle and $CQ = c$ being the perpendicular from C to QP,

$$\sin \chi = \frac{CQ}{CP};$$

and if PT is the tangent to the sphere from P,

$$CP = \frac{CT}{\sin \omega} = \frac{1}{\sin \omega};$$

therefore

$$\sin \chi = c \sin \omega. \tag{11}$$

The expression (8) now becomes

$$q = 3c^2 \sin^2 \omega \frac{\cos \omega + \cos^2 \omega}{4 + \cos \omega + \cos^2 \omega} \tag{12}$$

To find the maximum, we now vary ω, putting the differential coefficient of (12) equal to zero; we thus obtain an equation of the fifth degree. But as both the numerator and its differential coefficient are divisible by $(1+\cos\omega)$, the equation reduces to one of the fourth degree; which is

$$\cos^4\omega+\cos^3\omega+8\cos^2\omega-2\cos\omega-2=0.$$

This equation has two real roots; of these one is negative and does not concern us; the other is equal to 0·597309. This, then, is the value of $\cos\omega$ for which the polarisation is a maximum along a given line of sight. The locus of the maximum is a sphere concentric with the luminous sphere, and having a radius

$$\frac{1}{\sin\omega}=1\cdot2469,$$

or nearly one and a quarter times the radius of the luminous sphere. If any line of sight cut this sphere, a particle situated on it (the sphere) will polarise the light more than any other particle placed on the line of sight. If the line of sight lies wholly outside the sphere, then the particle which lies on the perpendicular from the centre of the sphere to the line of sight will be the one which will polarise the light most. Substituting the value of $\cos\omega$ into (11), we find the amount of maximum polarisation for different values of c. Thus, if $c=1$, or if the line of sight is a tangent to the Sun, the maximum value is $q=0\cdot372$, which gives $p=0\cdot229$. Three minutes away from the Sun we have already $q=0\cdot524$. The line of sight which touches the sphere of maximum polarisation forms an angle of $3'\,57''$ with the nearest point on the Sun's limb. The maximum polarisation for that line of sight is $q=0\cdot578$.

In order to show the rapid way in which the polarisation increases as the particle is moved away from the Sun, I have calculated in Table I. the values of q for light scattered from a particle in a direction at right angles to the line drawn from it to the centre of the luminous sphere. The angle which the line of sight makes with a line drawn to the Sun's centre is given in the first column. The solar diameter is supposed to be $16'$. It will be seen that, at a distance of four solar radii from the Sun's centre, the Sun very nearly behaves as a luminous point.

3.—A Luminous Sphere surrounded by an Atmosphere of Scattering Particles.

We now pass to the consideration of an atmosphere of scattering particles round the luminous sphere. It will be convenient to substitute for the variable ω the angle χ, connected with the former by

$$\sin\omega=k\sin\chi,$$

where

$$kc = 1.$$

Putting

$$\Delta\chi = \sqrt{1-k^2\sin^2\chi},$$

we find by (8) and (7)

$$2(g_0-g_1) = k^2\sin^4\chi\,\Delta\chi,$$
$$6g_0 = 4-\Delta\chi(4-k^2\sin^2\chi).$$

Let h be measured along a line of sight from Q (Fig. 2); then

$$\frac{c}{h} = \tan\chi,$$

$$-dh = \frac{c}{\sin^2\chi}\,d\chi.$$

We wish to compare the intensities of light received along different lines of sight; or, to speak more correctly, we wish to compare the intensities received within cones of small, but given, aperture $d\Omega$ which have different lines of sight as axes. If we consider that the number of particles contained within an element of such a cone is $R^2 d\Omega dh$, and that the intensity of light received from each such element varies inversely as R^2, we see that

$$d\Omega\int g f(c,\chi)\,dh$$

will be the intensity required if $f(c,\chi)$ represents the density of scattering matter along a line of sight. Leaving $d\Omega$ out of account, as we only compare intensities received within cones of equal aperture, we obtain, if I_0 is the intensity of light polarised radially and I_1 that polarised tangentially,

$$I_0-I_1 = c\int_0^{\frac{\pi}{2}} f(c,\chi)\,k^2\sin^2\chi\,\Delta\chi\,d\chi, \qquad (13)$$

$$I_0 = \frac{c}{3}\int_0^{\frac{\pi}{2}} f(c,\chi)\left[\frac{4}{\sin^2\chi}(1-\Delta\chi)+k^2\Delta\chi\right]d\chi. \qquad (14)$$

We first take the simplest case, that the density of scattering matter is constant and everywhere equal to unity.

We obtain, by easy transformations and the usual notation of elliptic integrals,

$$\int_0^{2\pi} d\chi\,\sin^2\chi\,\Delta\chi = \frac{1}{3k^2}\left[k'^2F_1+(k^2-k'^2)E_1\right],$$

$$\int_0^{2\pi} d\chi\,\frac{(1-\Delta\chi)}{\sin^2\chi} = E_1-k'^2F_1,$$

where $k'^2 = 1-k^2$.

Hence we find, remembering that c is the reciprocal of k,

$$3(I_0 - I_1) = k E_1 + \frac{k'^2}{k}(F_1 - E_1),$$

$$3I_0 = 5k E_1 - 4\frac{k'^2}{k}(F_1 - E_1),$$

$$3I_1 = 4k E_1 - 5\frac{k'^2}{k}(F_1 - E_1).$$

For the polarisation we obtain, writing $F_1 - E_1 = L_1$,

$$p = \frac{I_0 - I_1}{I_0 + I_1} = \frac{1}{9}\frac{k^2 E_1 + k'^2 L_1}{k^2 E_1 - k'^2 L_1}.$$

This quantity will increase or decrease for varying k with

$$\frac{k'^2 L_1}{k^2 E_1};$$

but we shall not stop here to prove that this quantity increases with increasing values of c, as the proof will be included under the more general case, which we now propose to treat. Tables II., III., IV. give some numerical values for the above expressions. The arrangement of the Tables will be explained further on.

We shall now suppose that the distribution of matter is only a function of the distance from the Sun's centre. This function is supposed to be expanded in inverse powers of the distance, and may contain a constant term.

In Fig. 2 we have

$$\frac{1}{CP} = \sin\omega = k \sin\chi.$$

We may therefore suppose the expansion to have taken place in powers of $k \sin\chi$. We shall consider first, the case of a distribution varying as the inverse nth power of the distance from the Sun's centre. In equations (13) and (14) we have to put

$$f(c, \chi) = a k^n \sin^n \chi,$$

and we shall choose our unit of density so that $a = 1$.

We obtain in this way

$$I_0 - I_1 = \int_0^{\frac{\pi}{2}} k^{n+1} \sin^{n+2}\chi \, \Delta\chi \, d\chi,$$

$$3I_0 = \int_0^{\frac{\pi}{2}} [4k^{n-1} \sin^{n-2}\chi (1 - \Delta\chi) + k^{n+1} \sin^n \chi \, \Delta\chi] \, d\chi.$$

For any given n, the exponent of $\sin\chi$ can, by partial integration, be depressed, and if n is even, the expressions can be finally reduced to elliptic integrals; if n is odd, the integrals can be expressed by means of circular and logarithmic functions.

We are here only concerned with the variation of the fraction $\frac{I_0-I_1}{I_0}$, and we can easily show that this fraction must increase with increasing c, or with decreasing k.

We adopt the following notation :—

$$P_n=\int_0^{\frac{\pi}{2}}\sin^n\chi\,\Delta\chi\,d\chi,$$

$$Q_n=\int_0^{\frac{\pi}{2}}\frac{\sin^n\chi}{\Delta\chi}\,d\chi.$$

It is easily found that

$$\frac{d.k^m P_n}{dk}=k^{m-1}[(m+1)P_n-Q_n],$$

and hence

$$\frac{d(I_0-I_1)}{dk}=k^n[(n+2)P_{n+2}-Q_{n+2}]=\frac{(n-1)}{k}(I_0-I_1)+k^n(3P_{n+2}-Q_{n+2}),$$

$$\frac{dI_0}{dk}=\frac{n-1}{k}I_0+k^n(P_n+Q_n).$$

If we expand

$$\frac{4}{3}.\frac{1-\Delta\chi}{k^2\sin^2\chi}+\frac{\Delta\chi}{3}$$

in powers of k^2, the constant term is found to be 1, the term containing k^2 will disappear, and the term containing k^{2p} will be

$$\frac{1.3\ .\ .\ .\ 2p-3}{2.4\ .\ .\ .\ 2p-2.2p}.\frac{p-1}{p+1}.k^{2p}\sin^{2p}\chi.$$

We find similarly, by expanding $\frac{1}{2}\left(\Delta\chi+\frac{1}{\Delta\chi}\right)$, the first term to be 1 and the second term to disappear; but the term containing k^{2p} will be

$$\frac{1.3\ .\ .\ .\ 2p-3}{2.4\ .\ .\ .\ 2p-2.2p}(p-1)\,k^{2p}\sin^{2p}\chi.$$

As all terms are positive in both cases, we conclude that for every value of k

$$\frac{4}{3}\cdot\frac{1-\Delta\chi}{k^2\sin^2\chi}+\frac{\Delta\chi}{3}<\frac{1}{2}\left(\Delta\chi+\frac{1}{\Delta\chi}\right);$$

or, multiplying both sides with $k^{n+1}\sin^n\chi$, and integrating,

$$I_0 < \frac{k^{n+1}}{2}(P_n+Q_n).$$

The increase or decrease of $\frac{I_0-I_1}{I_0}$ will depend on the sign of

$$\frac{1}{I_0-I_1}\cdot\frac{d(I_0-I_1)}{dk}-\frac{1}{I_0}\cdot\frac{dI_0}{dk}. \qquad (15)$$

As $\frac{dI_0}{dk}$ is always positive as well as $\frac{1}{I_0}$, this expression will be rendered algebraically larger if we substitute for I_0 the higher value just found. Substituting for $\frac{d(I_0-I_1)}{dc}$, $\frac{dI_0}{dc}$, and I_0-I_1, their values, the expression (15) becomes

$$\frac{1}{k}\cdot\left[1-\frac{Q_{n+2}}{P_{n+2}}\right] = -kQ_{n+4}. \qquad (16)$$

We see that $\frac{I_0-I_1}{I_0}$ always increases as k decreases; that is, as the line of sight moves away from the Sun. We have found therefore that: *The polarisation must increase with increasing distances from the Sun if the scattering matter is distributed according to any inverse power of the distance from the Sun.*

Tables II., III., and IV. contain some numerical calculations which I have made for different laws of distribution.

Table II. contains the intensity of the stronger component; Table III. gives the difference, I_0-I_1, between the two components; and Table IV. gives the values of $q=\frac{I_0-I_1}{I_0}$. The argument θ is given by $k=\sin\theta$. At the head of each column, the law according to which the scattering matter is supposed to be distributed is given. The first column gives the values for a constant distribution of matter. It will be seen that, up to the inverse 6th power and most likely beyond, the percentage of polarisation is much the same whatever law we take. In Table V. the corresponding values of θ and $k-1=c$ are given; $k-1$ is very nearly proportional to the angular distance from the Sun's centre. For the edge of the Sun $k=1$.

If the law of distribution of the scattering particles contains more than one term, the polarisation does not necessarily increase throughout with increasing distance from the Sun. Suppose the law to be expressed by

$$\Sigma A_n k^n \sin^n \chi,$$

we have, writing R_n for

$$\int_0^{\frac{\pi}{2}} \left[\frac{4}{3}\sin^{n-2}\chi . k^{-2}(1-\Delta\chi)+\frac{1}{3}\sin^n\chi\,\Delta\chi\right] d\chi.$$

$$I_0 = \Sigma A_n k^{n+1} R_n, \quad < \frac{1}{2}\Sigma A_n k^{n+1}(P_n+Q_n),$$

$$I_0 - I_1 = \Sigma A_n k^{n+1} P_{n+2},$$

$$\frac{dI_0}{dk} = \Sigma A_n (n-1) k^n R_n + \Sigma A_n k^n (P_n+Q_n),$$

$$\frac{d(I_0-I_1)}{dk} = \Sigma A_n (n-1) k^n P_{n+2} + \Sigma A_n k^n (3P_{n+2}-Q_{n+2}).$$

We observe that $\frac{d(I_0-I_1)}{dk}$ is always negative for values of k which are sufficiently near unity; for while P_{n+2} approaches a finite quantity, Q_{n+2} becomes infinitely large if Q is equal to 1.

The expression corresponding to (15) and (16) will be, if we multiply by k,

$$\frac{\Sigma_n A_n k^n P_{n+2}}{\Sigma' A_n k^n P_{n+2}} - \frac{\Sigma_n A_n k^n R_n}{\Sigma A_n k^n R_n} - \frac{\Sigma A_n k^n Q_{n+2}}{\Sigma A_n k^n P_{n+2}} + 1 \qquad (17)$$

If k is nearly 1, the third term becomes very large compared to the others, and hence *the polarisation close to the Sun must always increase with increasing distance from the Sun's centre.* As k becomes smaller, however, the positive terms may have the upper hand, and the polarisation may therefore approach a maximum.

In order to show this, suppose, for instance, that the distribution of matter contains only two terms, with indices n and t respectively. Bringing (17) under the same denominator, and remembering that

$$Q_{n+2} = P_{n+2} + k^2 Q_{n+4},$$

we find for the numerator

$$(t-n) A_n A_t k^{n+t} (R_n P_{t+2} - R_t P_{n+2}) - k^2 (A_n k^n Q_{n+4} + A_t k^t Q_{t+4})(A_n k^n R_n + A_t k^t R_t). \qquad (18)$$

If k is very small, the sign of the whole expression will depend on the sign of the lowest power of k. The lowest power in the

second term is k^{2n+2}. If $t > n+2$, this will be lower than the lowest power contained in the first term. In that case (18) is always negative for small values of k; that is, the polarisation will increase with increasing distance from the Sun. But if $t = n+1$, the first term contains the lowest powers of k. The constant term in R_n and P_n is

$$\int_0^{\frac{\pi}{2}} \sin^n \chi \, d\chi,$$

for which we write s_n. Thus we find for the lowest power of k

$$(t-n)\, A_n A_t s_n s_t \left[\frac{t+1}{t+2} - \frac{n+1}{n+2}\right].$$

This expression will have the same sign as A_n, A_t, and if, therefore, these two quantities are of the same sign, the differential coefficient of $\frac{I_0 - I_1}{I_0}$ will be positive for small values of k; that is, the polarisation will *decrease* with increasing distance from the Sun.

If A_n and A_t are of opposite sign, the polarisation will finally increase. If $t = n+2$, it may be positive or negative according to the relative value of A_r and A_t, but must always be negative if A_n and A_t are of opposite sign.

If the law of distribution contains more than two terms, then it is clear that for small values of k only the first two need be taken into account, and I arrive therefore at the following law :—

If the distribution of scattering matter is expanded in inverse powers of the distance from the Sun, the increase or decrease of polarisation for large distances from the Sun will depend on the first two terms only; if these are of opposite sign, the polarisation will finally increase with increasing distances from the Sun. If they are of the same sign, and if the exponent of $\frac{1}{r}$ *in the second term differs by more than 2 from the exponent in the first term, the polarisation will finally increase; if it differs by 1 only, the polarisation will decrease; if by 2, the final increase or decrease will depend on the value of the constant quantities.*

I have followed out the case where the expansion contains only two terms; but I shall only give the results of the investigation. If A_r and A_t are of opposite sign, the polarisation will always increase. If they are of the same sign and $t = n+1$, the polarisation decreases for small values of k. Now if either A_r or A_t becomes very small, it is clear that the maximum of polarisation which must take place is very far removed from the centre of the Sun; for we have seen that if either constant is zero, the polarisation must steadily increase. There must therefore be one relative value of A_n and A_t for which the maximum of polarisa-

tion is brought nearest to the Sun. The question is of interest, as in reality the corona shows a maximum of polarisation and we might suppose this maximum to be produced by such a distribution of matter.

As a first approximation, I find that if the distribution of matter takes place according to the law $\frac{A^n}{r^n} + \frac{A_t}{r^t}$, both A_n and A_t being positive, the value of A_t which brings the maximum of polarisation nearest the Sun is given by

$$A_t = A_n k^{n-t} \frac{s_n}{s_t} \sqrt{\frac{n+3}{n+4} \cdot \frac{n+1}{n+2} \div \frac{t+3}{t+4} \cdot \frac{t+1}{t+2}}, \qquad (19)$$

where s_n is again written for

$$\int_0^{\frac{\pi}{2}} \sin^n \chi \, d\chi.$$

The value of k at which the maximum takes place and which has to be substituted in (19) is given by

$$k^2 = \left(\frac{t+1}{t+2} - \frac{n+1}{n+2}\right) \alpha \div \left[(1-\alpha)\frac{n+3}{n+4} \cdot \frac{n+1}{n+2} + (1+\alpha)\frac{t+3}{t+4} \cdot \frac{t+1}{t+2}\right].$$

where $\alpha = \frac{t-n}{2}$.

These equations are true for any value of t larger than n, only if $t > n+2$. We have seen that the polarisation finally increases, and in this case a minimum of polarisation occurs after the maximum has been passed.

If, for instance, $n=0$, $t=2$, we find

$$k^2 = \frac{1}{5} \quad \text{and} \quad A_q = A_p \, 50 \sqrt{\frac{3}{5}}; \quad \theta = 26^\circ \, 34'.$$

The maximum therefore takes place about 20 minutes away from the Sun's limb. Tables II., III., and IV. contain in the last column the calculations for this special case. Table IV. shows the maximum of polarisation at the point indicated. As the difference between t and n gets larger, the maximum moves nearer and nearer the Sun, and finally approaches a value which we obtain by putting $t=\infty$, $n=0$. We find in this special case,

$$k^2 = 0{\cdot}8, \quad \text{and hence} \quad \theta = 63^\circ \; 6'.$$

In this extreme case, however, it is clear that A_q becomes infinite. An approach to it in the actual corona might be found if the presence of scattering matter was due to two different

causes; one of which produced an even distribution throughout the corona, and the other of which produced a very large but rapidly diminishing amount close to the body of the Sun. In that case we might observe a maximum of polarisation near the point indicated. Outside this maximum the polarisation would diminish, reach a minimum, and finally increase again.

It is, however, clear that the maximum which takes place in the corona is due to a different cause; for if the whole corona was only formed by scattering matter, the polarisation ought to approach a constant value as we move away from the Sun, and this constant value could not be below $q = 0{\cdot}5$. In reality the polarisation rapidly diminishes and very soon a point in the corona is reached at which no polarisation can be observed; the corona must therefore contain some matter which is either self-luminous or too large to polarise the light while scattering it.

4. Light Scattered by an Atmosphere of Small Particles surrounding a Luminous Point.

If, instead of a luminous sphere, we have only a luminous point, the investigation is much simplified. Let the distribution of matter vary as r^{-n}; then the polarisation in a radial plane will be

$$I_0 = A\int_0^\infty dh\,\frac{1}{r^{n+2}},$$

and in a perpendicular plane

$$I_1 = A\int_0^\infty \frac{\cos^2\chi}{r^{n+2}}\,dh,$$

where, as before,

$$dh = -\frac{c}{\sin^2\chi}\,d\chi \quad \text{and} \quad r = \frac{c}{\sin\chi}.$$

Hence we have, if $A = 1$,

$$I_0 = \frac{1}{c^{n+1}}\int_0^{\frac{\pi}{2}} \sin^n\chi\,d\chi,$$

$$I_0 - I_1 = \frac{1}{c^{n+1}}\,\frac{n+1}{n+2}\int_0^{\frac{\pi}{2}} \sin^n\chi\,d\chi.$$

For the polarisation we obtain

$$q = \frac{I_0 - I_1}{I_0} = \frac{n+1}{n+2}.$$

The polarisation is therefore independent of c. *If the distribution of matter takes place according to any inverse power of*

the distance, the polarisation is constant and independent of the distance from the luminous point.

If the density of scattering matter is constant, $n = 0$; hence

$$q = \frac{1}{2} \quad \text{and} \quad p = \frac{1}{3}.$$

A third part of the whole light in this case will be polarised. Our formulæ are, of course, not applicable to small distances from the luminous point. For $c = 0$ the polarisation must necessarily vanish. Close to the luminous point there will be, therefore, a very rapid increase of polarisation; which, after this increase, will remain constant.

If the distribution of matter takes place according to the law

$$\frac{A_n}{r^n} + \frac{A_t}{r^t},$$

we find

$$I_0 - I_1 = \frac{A_n}{c^{n+1}} s_{n+2} + \frac{A_t}{c^{t+1}} s_{t+2},$$

$$I_0 = \frac{A_n}{c^{n+1}} s_n + \frac{A_t}{c^{t+1}} s_t.$$

Putting $t = n + l$, we find

$$\frac{I_0 - I_1}{I_0} = \frac{A_n c^l s_{n+2} + A_t s_{t+2}}{A_n c^l s_n + A_t s_t}.$$

Differentiating with respect to c, the denominator will contract into

$$l c^{l-1} A_n A_t (s_t s_{n+2} - s_n s_{t+2}), = l c^{l-1} A_n A_t s_n s_t \left(\frac{n+1}{n+2} - \frac{t+1}{t+2}\right).$$

This expression will always have the opposite sign to $A_n A_t$, and can never be zero. Hence,

If the distribution of matter surrounding a luminous point is expressed by the law

$$\frac{A_n}{r^n} + \frac{A_t}{r^t},$$

the polarisation, as looked at from a point outside the scattering atmosphere, will steadily increase if A_t is negative; it will steadily decrease if A_t is positive.

5. Light Scattered from a Partly Self-luminous Atmosphere of Small Particles.

We have hitherto only been considering cases which are very different from the one we have to deal with in the solar

atmosphere. The rapid decrease of polarisation with increasing distances from the Sun, as well as the comparatively small amount of observed polarisation, shows that a large part of the light is not due to scattering particles. This light may either be produced by incandescence, or by particles which are too large to polarise the light in the act of scattering it. If unpolarised light of intensity 2A be added to the light due to the scattering of particles, it is easy to see that, by taking A large enough, we shall be able to produce a maximum of polarisation in any place outside a certain circle surrounding the Sun. The intensity of the whole light will be $I_0 + I_1 + 2A$. Hence, the part which is polarised will be

$$\frac{I_0 - I_1}{I_0 + I_1 + 2A}.$$

In order that this should be a maximum, we must have

$$(I_0 + I_1 + 2A)\frac{d(I_0 - I_1)}{dc} = I_0 - I_1 \frac{d(I_0 + I_1 + 2A)}{dc} = 0.$$

Supposing A to be constant first, the above equation reduces to

$$(I_0 + A)\frac{d(I_0 - I_1)}{dc} - (I_0 - I_1)\frac{dI_0}{dc} = 0,$$

or

$$A\frac{d(I_0 - I_1)}{dc} = -I_0^2 \frac{d}{dc}\left(\frac{I_0 - I_1}{I_0}\right).$$

This equation determines A if I_0 and I_1 are given as functions of c; that is, if the law of distribution of the scattering particles is known. We observe first, that close to the Sun the differential coefficients on both sides have been shown to be always positive. In that case A ought to be negative, which has no meaning in our problem. We arrive therefore at the important conclusion:—

Close to the Sun the polarisation always increases, however large the intensity of the unpolarised light may be which is superposed to the light due to the scattering particles.

This law remains still correct if A is variable. If A is a constant, it will begin to be positive when $\frac{d(I_0 - I_1)}{dc}$ begins to be negative. If the distribution varies as the inverse nth power of the distance, this point is given by

$$Q_{(n+2)} = (n + 2)\, P_{(n+2)}.$$

Referring to Table III., we find for a constant distribution of matter this value to be near $\theta = 52^\circ{\cdot}5$, or about 4 minutes away from the Sun. As n increases, the point at which a maxi-

mum of polarisation may begin to take place gets nearer to the Sun. In order to show what intensity of natural light would be necessary to bring about a maximum of polarisation at a given point for various laws of distribution, I have calculated in Table VI. the proportion $\frac{I_0+I_1}{I_0+I_1+2A}$ of the scattered to the total light for various values of θ. I have added in each compartment the value of $q=\frac{I_0-I_1}{I_0+A}$ for the same point. In the Table the maximum of polarisation is supposed to take place at the distance from the Sun's centre fixed for each row by the affixed value of θ. The head of each column gives the law of distribution of scattering matter. The number at the top of each compartment fixes the polarisation; the number underneath indicates what must be the proportion of scattered to natural light which produces a maximum of polarisation at that point.

In reality the light due to self-luminosity and other causes varies with the distance of the Sun. The law of variation is one of our unknown quantities. We now turn to treat this general case.

6. The Solar Corona.

We write J for the total intensity and p for the observed polarisation. We have

$$J = I_0 + I_1 + 2A,$$

$$p = \frac{I_0-I_1}{J};$$

and hence

$$\frac{1}{p}\frac{dp}{dc} = \frac{1}{I_0-I_1}\frac{d(I_0-I_1)}{dc} - \frac{1}{J}\frac{dJ}{dc}. \qquad (20)$$

p and $\frac{dp}{dc}$ are quantities which we can observe. $\frac{1}{J}\frac{dJ}{dc}$ is the ratio of the increase of intensity to the total intensity, and can also be observed. Hence we can, by observation alone, find the value of $\frac{1}{I_0-I_1}\frac{d(I_0-I_1)}{dc}$ for different parts of the corona. Assuming the distribution of scattering matter to take place according to a law $a+\frac{b}{r}+\frac{c}{r^2}+\ldots$, we can, by constructing tables corresponding to the different terms in the expansion, find out what values of a, b, c, &c. agree most nearly with observation.

We may, if the observations are sufficiently accurate, for instance, find out whether a is zero or not. For the limiting value of $\frac{1}{I_0-I_1}\frac{d(I_0-I_1)}{dc}$ for small values of k is $-(n+1)k$

where n is the lowest exponent of r which occurs in the expansion. We may thus hope to settle the important point whether the scattering matter is falling into the Sun, or is projected outwards. If it is falling into the Sun, we expect a to be finite; if it is projected outwards, a will be zero. Having found a law which agrees with observed facts, we deduce easily all the unknown quantities; for, knowing I_0 and I_1 for different places in the corona, we find

$$J = \frac{I_0 - I_1}{p},$$

$$2A = \frac{I_0 - I_1}{p} - (I_0 + I_1) = \frac{1-p}{p} I_0 - \frac{1+p}{p} I_1;$$

and, by differentiation,

$$2\frac{dA}{dc} = \frac{1-p}{p}\frac{dI_0}{dc} - \frac{1+p}{p}\frac{dI_1}{dc} - \frac{I_0 - I_1}{p}\frac{dp}{dc}.$$

For the maximum of polarisation the last term is equal to zero, and we also have by (20)

$$\frac{1}{J}\frac{dJ}{dc} = \frac{1}{I_0 - I_1}\frac{d(I_0 - I_1)}{dc}.$$

The only published measurements, as far as I know, of the polarisation of the corona have been taken by Mr. Winter during the eclipse of 1871. He found, at a distance from the Sun's limb which he estimated to be about 10 minutes, $p = \cdot 26$. Mr. Winter did not observe the place of maximum polarisation. It is very improbable that this maximum was further away from the Sun than 10 minutes. Considering that Mr. Winter does not say whether his polarimeter has been properly tested, and did not actually measure the distance from the Sun, it would not be wise to attach too much importance to his numbers. I shall discuss them only to show how even a solitary observation can give us some information. Assuming the maximum of polarisation to have taken place just at the point observed by Mr. Winter, I have calculated the following data for the three laws of distribution given at the head of each column:

$p = 0{\cdot}26.$

	r^0	r^{-2}	r^{-4}
$\frac{I_0 + I_1}{J}$	·97	·58	·50
$\frac{dA}{dc}$	+·23	− ·09	− ·07
$\frac{1}{J}\frac{dJ}{dc}$	−·37	−1·55	−2·75.

We see that if the density of the scattering matter was constant in the corona, Mr. Winter's observations would show that

over nine-tenths of the light was due to scattering matter. If the density of the scattering matter varied inversely as the square of the distance from the Sun's centre, only about one-half of the light would be due to that cause. If we assume the first law to be true, the light not due to scattering particles would increase at an almost impossible rate as we go away from the Sun, while it would decrease if we assume the second or third law to be true. The values given in the last row might have been observed, and would have told us which of the three laws agreed most nearly with observed facts. At present we can only say that the first law is very improbable, as the natural light can hardly increase with the distance from the Sun, while the density of the scattering particles remains constant. Considering that the maximum of polarisation was very likely nearer the Sun than we have assumed, we shall not be far wrong in concluding that the intensity of the scattered light was not much more than one-half of that of the total light during the eclipse of 1871.

Strictly speaking, the observations ought to be made for all different colours; but this will be hardly possible during the short time available in an eclipse. As, however, the scattered light will have a different composition from the light due to other causes, it would be of the utmost importance to get an idea of the composition of light in the solar corona. An instrument invented by Mr. Diro Kitao, and called by him 'Leukoskop,' will be very useful for this purpose.

7. Numerical Calculations.

In order to calculate the two components and the polarisation, if the distribution takes place according to the inverse nth power of the distance from the Sun's centre, we observe that

$$P_0 = E_1,$$

$$k^2 P_2 = \int_0^{\frac{\pi}{2}} k^2 \sin^2\chi \, \Delta\chi \, d\chi = \frac{1}{3}[k^2 E_1 + k'^2 (F_1 - E_1)],$$

and for any value of n higher than 2 we find, by partial integration,

$$(n+1) k^2 P_n = (nk^2 + n - 2) P_{n-2} - k^2 (n-3) P_{n-4}.$$

After having calculated in this way successively $k^2 P_2$, $k^4 P_4$, ... up to $k^{n+2} P_{n+2}$, we find

$$I_0 - I_1 = k^{n+1} P_{n+2},$$

$$I_0 = \frac{1}{3}[k^{n+1} P_n - 4k^{n-1} P_{n-2}],$$

and

$$\frac{d(I_0 - I_1)}{d\sigma} = -k^2 \frac{dI_0}{dk} = k^{n+2}[Q_{n+2} - (n+2) P_{n+2}].$$

By successively applying the identity

$$k^2 Q_{(n+2)} = Q_n - P_n,$$

we find

$$\frac{d(I_0 - I_1)}{dc} = (F_1 - E_1) - k^2 P_2 - k^4 P_4 - \ldots k^n P_n - (n+2) P_{n+2}.$$

Similarly

$$\frac{dI_0}{dc} = -k^2 \frac{dI_0}{dk} = -k^{n+2} (Q_n + P_n) - (n-1) k I_0$$

$$= -k^2 [(F_1 - E_1) - k^2 P_2 - k^4 P_4 \ldots - k^{n-2} P_{n-2} + k^n P_n] - (n-1) k I_0.$$

Table I.

Minutes of Arc.	$2g_0$	$2g_1$	q
16	1·333	1·333	0·000
19	0·742	0·359	0·516
22	0·539	0·176	0·673
25	0·414	0·099	0·761
28	0·328	0·060	0·816
31	0·267	0·039	0·853
34	0·222	0·027	0·880
37	0·187	0·019	0·900
40	0·160	0·014	0·916
52	0·095	0·004	0·951
64	0·062	0·002	0·968

Table II., giving the value of I_0.

θ	r^0	r^{-2}	r^{-4}	r^{-6}	$r^0 - r^{-2}$	$a = 38{\cdot}73$ $r^{-2} - r^{-4}$	$r^0 + ar^{-2}$
15°·0	0·4066	0·0136	0·0007	0·0000	0·3930	0·0129	0·9337
22·5	0·6013	0·0441	0·0048	0·0006	0·5573	0·0392	2·3074
30·0	0·7863	0·0984	0·0185	0·0038	0·6879	0·0799	4·5962
37·5	0·9590	0·1780	0·0495	0·0153	0·7810	0·1285	7·8537
45·0	1·1171	0·2804	0·1053	0·0439	0·8367	0·1751	11·9769
52·5	1·2593	0·3992	0·1891	0·0993	0·8600	0·2102	16·7214
60·0	1·3841	0·5255	0·2973	0·1865	0·8586	0·2282	21·7378
67·5	1·4904	0·6486	0·4190	0·2997	0·8418	0·2296	26·6102
75·0	1·5765	0·7567	0·5368	0·4210	0·8198	0·2199	30·8821
82 5	1·6386	0·8370	0 6289	0·5215	0·8016	0·2080	34·0547
90·0	1·6667	0·8722	0·6694	0·5664	0·7945	0·2028	35·4457

Table III., giving the values of $I_0 - I_1$.

θ	r^0	r^{-2}	r^{-4}	r^{-6}	$r^0 - r^{-2}$	$r^{-2} - r^{-4}$	$r^0 + ar^{-2}$ ($a = 38\cdot73$)
15°	0·1981	0·0099	0·0006	0·0000	0·1882	0·0094	0·5823
22·5	0·2835	0·0309	0·0038	0·0005	0·2518	0·0272	1·4814
30·0	0·3537	0·0655	0·0136	0·0030	0·2882	0·0519	2·8901
37·5	0·4055	0·1104	0·0337	0·0109	0·2951	0·0766	4·6793
45·0	0·4370	0·1586	0·0650	0·0281	0·2784	0·0937	6·5796
52·5	0·4482	0·2015	0·1029	0·0558	0·2467	0·0985	8·2507
60·0	0·4406	0·2308	0·1387	0·0887	0·2098	0·0922	9·3802
67·5	0·4179	0·2417	0·1621	0·1164	0·1762	0·0796	9·7781
75·0	0·3857	0·2342	0·1671	0·1285	0·1515	0·0672	9·4562
82·5	0·3526	0·2150	0·1555	0·1221	0·1376	0·0595	8·6795
90·0	0·3333	0·2000	0·1429	0·1111	0·1333	0·0571	8·0793

Table IV., giving value of $\frac{I_0 - I_1}{I_0}$.

θ	r^0	r^{-2}	r^{-4}	r^{-6}	$r^0 - r^{-2}$	$r^{-2} - r^{-4}$	$r^0 + ar^{-2}$
15·0°	0·4872	0·7292	0·8073	0·8423	0·4788	0·7247	0·6236
22·5	0·4715	0·7022	0·7777	0·8160	0·4518	0·6929	0·6420
30·0	0·4499	0·6657	0·7348	0·7685	0·4190	0·6498	0·6288
37·5	0·4228	0·6199	0·6806	0·7093	0·3779	0·5964	0·5958
45·0	0·3912	0·5656	0·6167	0·6400	0·3327	0·5349	0·5494
52·5	0·3559	0·5046	0·5443	0·5612	0·2868	0·4689	0·4934
60·0	0·3183	0·4392	0·4664	0·4758	0·2443	0·4038	0·4315
67·5	0·2804	0·3726	0·3868	0·3884	0·2093	0·3468	0·3675
75·0	0·2447	0·3095	0·3118	0·3053	0·1848	0·3054	0·3062
82·5	0·2152	0·2569	0·2472	0·2341	0·1716	0·2865	0·2548
90·0	0·2000	0·2293	0·2136	0·1962	0·1678	0·2818	0·2279

Table V.

θ	c	θ	c
15°	3·864	60·0°	1·155
22·5	2·613	67·5	1·082
30·0	2·000	75·0	1·035
37·5	1·643	82·5	1·009
45·0	1·414	90·0	1·000
52·5	1·261		

Table VI.

The numbers at the top of each compartment denote $\frac{I_0 - I_1}{I_0 + A}$.

The numbers at the bottom of each compartment denote $\frac{I_0 + I_1}{I_0 + I_1 + 2A}$.

θ	r^0	r^{-2}	r^{-4}	r^{-6}
°				
15·0	0·4612	0·714	0·807	0·8
	0·9307	0·969	—	—
22·5	0·4122	0·669	6 755	0·78
	0·8416	0·930	0·955	—
30·0	0·3427	0·6053	0·6924	0·739
	0·7125	0·8699	0·9110	0·941
37·5	0·2523	0 5224	0·6115	0·655
	0·5029	0·7872	0·8534	0·888
45·0	0·1410	0·4204	0·5131	0·559
	0·3120	0·6749	0·7742	0·824
52·5	0·0104	0·3000	0·3970	0·4457
	0·0235	0·5229	0·6624	0·7167
60·0		0·1307	0·2207	0·2644
		0·2485	0·4079	0·4879
67 5			0·1202	0·1619
			0·2666	0·3655
75·0				0·0192
				0·0538

A Comparison between the Right Ascensions and North Polar Distances of the Nautical Almanac and the General Cape Catalogue for 1880. By E. J. Stone, M.A., F.R.S.

The following paper contains a comparison between the results of my Cape Catalogue, now passing through the press, and the Right Ascensions and North Polar Distances of the stars given in the *Nautical Almanac* for 1880.

The places of the principal stars given in the *Nautical Almanac* are chiefly based upon the numerous and long-continued Greenwich observations. These places, if not entirely free from systematic errors, must have their errors confined within small limits. It appeared to me, therefore, desirable that the Cape results should be compared with these *Nautical Almanac* places before the Cape Catalogue was finally committed to the press. The

results obtained will, I think, be found sufficiently interesting to justify their publication in the proceedings of the Society.

The comparison here made is, however, by no means a favourable one for the exhibition of the accuracy obtained in the Cape work. It was no part of my plan, at the Cape, to obtain a large number of observations of the principal stars. These *Nautical Almanac* stars have therefore not been observed more frequently than the smallest stars contained in the Cape Catalogue; whilst the position of many of the *Nautical Almanac* stars has been unfavourable for accurate observation at the Cape.

All the results, whether discordant or not, have been given. The differences have been inclosed in parentheses, and not used when the *Nautical Almanac* places may, to some extent, depend upon Cape observations, or when the stars are double stars and the centre of the mass has been observed, or when the proper motions are very large and, perhaps, variable, as in the cases of *Sirius* and *Procyon*.

Comparison between the Results of the Cape Catalogue for 1880 *and those of the Nautical Almanac for the same Year.*

Name of Star.	*N.A.* R.A. h	m	s	Seconds of Cape R.A. s	Cape−*N.A.* s	*N.A.* N.P.D. °	′	″	Seconds of Cape N.P.D. ″	Cape−*N.A.* ″	No. of Cape Obs. N.P.D.
α Andromedæ	0	2	11·17	11·14	−0·03	61	34	19·72	20·58	+0·86	2
γ Pegasi	0	7	3·43	3·41	−0·02	75	29	1·86	0·92	−0·94	7
ι Ceti	0	13	18·71	18·75	+0·04	99	29	22·61	22·15	−0·46	8
β Hydri	0	19	25·36	25·32	(−0·04)	167	55	49·42	48·68	(−0·74)	73
12 Ceti	0	23	54·82	54·82	0·00	94	37	14·19	14·32	+0·13	9
β Ceti	0	37	33·84	33·85	+0·01	108	38	44·46	44·05	−0 41	3
δ Piscium	0	42	27·33	27·32	−0·01	83	4	6·31	6·02	−0·29	3
ϵ Piscium	0	56	43·01	42·95	−0·06	82	45	23·50	22·89	−0·61	5
β Andromedæ	1	3	0·97	1·07	+0·10	55	0	57·32	56·25	−1·07	2
θ Ceti	1	18	1·45	1·50	+0·05	98	48	10·75	11·21	+0·46	4
η Piscium	1	25	3·75	3·79	+0·04	75	16	23·89	24·06	+0·17	5
α Eridani	1	33	14·54	14·60	(+0·06)	147	50	48·60	49·01	(+0·41)	72
ν Piscium	1	35	11·14	11·18	+0·04	85	7	13·63	13·14	−0·49	4
ο Piscium	1	39	3·43	3·43	0·00	81	26	48·95	49·16	+0·21	3
β Arietis	1	48	0·64	0·71	+0·07	69	46	45·59	45·45	−0·14	3
α Arietis	2	0	24·59	24·56	−0·03	67	6	21·10	20·35	−0·75	5
67 Ceti	2	10	59·83	59·82	−0·01	96	58	33·88	33·40	−0·48	4
ξ^2 Ceti	2	21	46·73	46·76	+0·03	82	4	43·81	43·31	−0·50	4

Name of Star.	*N.A.* R.A.			Seconds of Cape R.A.	Cape−*N.A.*	*N.A.* N.P.D.			Seconds of Cape N.P.D.	Cape−*N.A.*	No. of Cape Obs. N.P.D.
	h	m	s	s	s	°	′	″	″	″	
γ^2 Ceti	2	37	4·97	4·98	(+0·01)	87	16	16·22	14·14	−2·08	2
σ Arietis	2	44	52·03	52·09	+0·06	75	24	48·23	46·96	−1·27	2
α Ceti	2	56	0·39	0·39	0·00	86	22	55·84	55·37	−0·47	5
δ Arietis	3	4	46·10	46·13	+0·03	70	43	41·92	41·55	−0·37	3
α Persei	3	15	45·66	45·62	−0·04	40	34	3·30	1·68	−1·62	4
o Tauri	3	18	21·43	21·37	−0·06	81	23	40·73	40·69	−0·04	2
ϵ Eridani	3	27	16·61	16·63	+0·02	99	51	56·91	55·39	−1·52	5
η Tauri	3	40	21·12	21·14	+0·02	66	16	2·70	0·53	−2·17	1
γ Hydri	3	49	6·80	6·89	(+0·09)	164	36	22·03	(23·96)	(+1·93)	23
γ^1 Eridani	3	52	25·78	25·79	+0·01	103	51	4·30	3·64	−0·66	4
A Tauri	3	57	36·09	36·01	−0·08	68	14	51·72	51·60	−0·12	4
o^1 Eridani	4	6	0·41	0·46	+0·05	97	9	6·48	6·28	−0·20	4
γ Tauri	4	12	57·90	57·87	−0·03	74	39	49·01	48·74	−0·27	3
ϵ Tauri	4	21	36·56	36·57	+0·01	71	5	14·21	13·49	−0·72	2
α Tauri	4	29	2·13	2·11	−0·02	73	44	0·43	0·29	−0·14	4
μ Eridani	4	39	30·15	30·13	−0·02	93	28	33·07	34·43	+1·36	2
ι Aurigæ	4	49	10·75	10·77	+0·02	57	1	32·54	32·38	−0·16	2
ϵ Leporis	5	0	22·82	22·82	0·00	112	31	61·12	59·62	−1·50	7
α Aurigæ	5	7	49·55	49·54	−0·01	44	7	34·21	33·61	−0·60	10
β Orionis	5	8	46·23	46·22	−0·01	98	20	30·56	29·62	−0·94	5
β Tauri	5	18	42·45	42·39	−0·06	61	29	45·13	43 84	−1·29	3

δ Orionis	5	25	52·58	52·57	−0·01	90	23	22·42	21·88	−0·54	5
α Leporis	5	27	26·27	26·23	−0·04	107	54	34 05	33·91	−0·14	3
ϵ Orionis	5	30	7·41	7·46	+0·05	91	16	48·28	48·47	+0·19	3
α Columbæ	5	35	18·27	18·22	−0·05	124	8	21·11	20·18	−0·93	7
κ Orionis	5	42	3·87	3·89	+0·02	99	42	49·38	48·47	−0·91	3
α Orionis	5	48	40·51	40·48	−0·03	82	37	1·25	0·15	−1·10	3
ν Orionis	6	0	43·23	43·24	+0·01	75	13	7·66	7·70	+0·04	2
η Geminorum	6	7	38·02	38·12	+0·10	67	27	36·34	36·88	+0·54	2
μ Geminorum	6	15	42·07	42·02	−0·05	67	25	36·29	35·82	−0·47	2
α Argûs	6	21	17·21	17·23	+0·02	142	37	50·24	50·04	(−0·20)	3
γ Geminorum	6	30	46·73	46·73	0·00	73	29	59·70	59·57	−0·13	3
ξ Geminorum	6	38	33·25	33·27	+0·02	76	58	36·27	35·12	−1·15	2
α Canis Majoris	6	39	51·58	51·38	(−0·20)	106	33	9·67	11·29	(+1·62)	6
θ Canis Majoris	6	48	36·86	36·88	+0·02	101	53	22·20	22·28	+0·08	2
ϵ Canis Majoris	6	53	54·59	54·51	−0·08	118	48	35·61	34·93	−0·68	4
γ Canis Majoris	6	58	19·80	19·75	−0·05	105	27	25·43	25·98	+0·55	3
δ Geminorum	7	12	57·39	57·36	−0·03	67	47	54·23	54·25	+0·02	3
β Canis Minoris	7	20	38·56	38·56	0·00	81	28	12·64	12·34	−0·30	3
α^2 Geminorum	7	26	56·55	56·54	−0·01	57	50	59·70	59·12	−0·58	2
α Canis Minoris	7	33	1·22	1·12	(−0·10)	84	28	8·93	7·14	(−1·79)	3
β Geminorum	7	37	58·28	58·25	−0·03	61	41	7·72	6·74	−0·98	2
ξ Argûs	7	44	14·87	14·81	−0·06	114	33	33·88	34·81	+0·93	3

Name of Star.	*N.A.* R.A. h	m	s	Seconds of Cape R.A. s	Cape−*N.A.* s	*N.A.* N.P.D. °	′	″	Seconds of Cape N.P.D. ″	Cape−*N.A.* ″	No. of Cape Obs. N.P.D.
6 Cancri	7	56	8·74	8·76	+0·02	61	52	14·94	14·36	−0·58	6
15 Argûs	8	2	26·02	25·96	−0·06	113	57	33·90	33·01	−0·89	6
β Cancri	8	10	0·39	0·42	+0·03	80	26	44·52	44·90	+0·38	2
η Cancri	8	25	46·04	46·06	+0·02	69	9	9·13	8·88	−0·25	3
γ Cancri	8	36	20·37	20·36	−0·01	68	6	3·34	3·19	−0·15	3
ε Hydræ	8	40	25·23	25·18	−0·05	83	8	31·37	30·91	−0·46	3
α Cancri	8	51	55·35	55·41	+0·06	77	40	43·54	43·36	−0·18	2
κ Cancri	9	1	14·81	14·81	0·00	78	50	59·78	58·48	−1·30	2
83 Cancri	9	12	16·88	16·93	+0·05	71	47	13·35	12·13	−1·22	1
ι Argûs	9	13	52·62	(52·68	+0·06)	148	46	19·07	(19·82	+0·75)	3
α Hydræ	9	21	41·37	41·37	0·00	98	8	21·80	21·57	−0·23	6
ο Leonis	9	34	44·67	44·68	+0·01	79	33	44·97	45·52	+0·55	3
ε Leonis	9	39	2·30	2·25	−0·05	65	40	27·01	26·57	−0·44	2
μ Leonis	9	45	56·15	56·10	−0·05	63	25	43·39	42·28	−1·11	2
π Leonis	9	53	52·27	52·28	+0·01	81	22	51·19	50·90	−0·29	5
α Leonis	10	1	58·80	58·78	−0·02	77	26	49·01	48 36	−0·65	3
γ^1 Leonis	10	13	21·28	21·28	0·00	69	33	7·72	7·20	−0·52	2
μ Hydræ	10	20	17·21	17·18	−0·03	106	13	28·21	27·39	−0·82	2
ρ Leonis	10	26	29·54	29·52	−0·02	80	4	36·41	34·94	−1·47	1
η Argûs	10	40	24·46	(24·54	+0·08)	149	3	14·00	(14·05	+0·05)	4
l Leonis	10	42	56·89	56·92	+0·03	78	49	13·13	11·28	−1·85	2

d Leonis	10	54	21·72	21·76	+0·04	85	44	19·48	18·92	−0·56	3
χ Leonis	10	58	49·57	49·58	+0·01	82	0	57·35	54·98	−2·37	3
δ Leonis	11	7	43·54	43·47	−0·07	68	49	9·09	9·36	+0·27	3
δ Crateris	11	13	20·50	20·46	−0·04	104	7	46·04	45·61	−0·43	3
τ Leonis	11	21	45·90	45·97	+0·07	86	28	58·46	59·72	+1·26	3
υ Leonis	11	30	48·22	48·24	+0·02	90	9	41·22	40·73	−0·49	3
β Leonis	11	42	56·26	56·24	−0·02	74	45	25·91	25·63	−0·28	3
π Virginis	11	54	43·41	43·41	0·00	82	42	60·91	58·15	−2·76	2
ϵ Corni	12	3	57·29	57·21	−0·08	111	57	8·25	8·06	−0·19	3
β Chamæleontis	12	11	20·53	20·40	(−0·13)	168	38	44·29	45·19	(+0·90)	12
η Virginis	12	13	45·94	45·96	+0·02	89	59	59·43	59·34	−0·09	2
α Crucis (Mean)	12	19	56·35	56·42	(+0·07)	152	26	2·24	3·06	(+0·82)	8
δ^2 Corvi	12	23	39·50	39·39	−0·11	105	50	50·30	49·95	−0·35	2
β Corvi	12	28	4·96	5·01	+0·05	112	43	58·90	58·46	−0·44	3
γ Virginis (Mean)	12	35	34·83	34·75	(−0·08)	90	47	29·24	27·43	(−1·81)	3
δ Virginis	12	49	33·55	33·54	−0·01	85	57	1·36	0·77	−0·59	2
α Canum Venat.	12	50	24·73	24·72	−0·01	51	1	59·51	60·54	+1·03	5
ϵ Virginis	12	56	12·20	12·19	−0·01	78	23	43·88	43·68	−0·20	1
θ Virginis	13	3	44·21	44·23	+0·02	94	53	52·84	53·01	+0·17	7
α Virginis	13	18	52·27	52·26	−0·01	100	32	4·18	4·47	+0·29	4
ζ Virginis	13	28	34·75	34·72	−0·03	89	58	54·25	54·49	+0·24	4
τ Boötis	13	41	33·58	33·56	−0·02	71	56	40·23	41·97	+1·74	1

Name of Star.	*N.A.* R.A. h	m	s	Seconds of Cape R.A. s	Cape−*N.A.* s	*N.A.* N.P.D. °	′	″	Seconds of Cape N.P.D. ″	Cape−*N.A.* ″	No. of Cape Obs. N.P.D.
η Boötis	13	48	58·28	58·19	−0·09	70	59	60·58	59·91	−0·67	1
β Centauri	13	55	21·99	22·09	(+0·10)	149	47	35·15	35·09	(−0·06)	51
τ Virginis	13	55	32·39	32·38	−0·01	87	52	27·92	26·13	−1·79	1
α Boötis	14	10	11·30	11·23	−0·07	70	11	30·53	30·97	+0·44	4
f Boötis	14	20	52·57	52·48	−0·09	70	13	58·33	58·77	+0·44	1
ρ Boötis	14	26	39·52	39·43	−0·09	59	6	3·90	3·78	−0·12	1
α^2 Centauri	14	31	27·14	27·26	(+0 12)	150	20	27·99	24·19	(−3·80)	49
α Libræ	14	44	14·47	14·46	−0·01	105	32	31·68	30·97	−0·71	2
ψ Boötis	14	59	18·26	18·19	−0·07	62	35	1·20	2·46	+1·26	1
β Libræ	15	10	32·97	32·99	+0·02	98	56	20·56	21·25	+0·69	3
α Coronæ	15	29	36·46	36·40	−0·06	62	52	49·71	49·40	−0·31	1
α Serpentis	15	38	21·45	21·45	0·00	83	11	45·01	44·26	−0·75	3
ϵ Serpentis	15	44	50·06	50·11	+0·05	85	9	36·34	36·83	+0·49	2
β^1 Scorpii	15	58	27·61	27·62	+0·01	109	28	32·56	32·55	−0·01	4
δ Ophiuchi	16	8	3·39	3·41	+0·02	93	23	2·23	3·17	+0·94	4
γ Herculis	16	16	37·58	37·59	+0·01	70	33	50·00	50·76	+0·76	1
α Scorpii	16	22	3·05	2·97	−0·08	116	9	50·82	50·59	−0·23	13
ζ Ophiuchi	16	30	33·09	33·08	−0·01	100	19	22·03	20·99	−1·04	1
α Trianguli Aust.	16	35	58·32	58·32	0·00	158	48	15·87	16·08	+0·21	22
κ Ophiuchi	16	51	59·23	59·28	+0·05	80	26	13·58	13·74	+0·16	2
η Ophiuchi	17	3	29·75	29·78	+0·03	105	34	29·03	29·18	+0·15	7

α^1 Herculis	17	9	10·54	10·53	−0·01	75	28	18·40	18·87	+0·47	2
θ Ophiuchi	17	14	38·39	38·35	−0·04	114	52	40·03	40·35	+0·32	4
σ Ophiuchi	17	20	33·63	33·75	+0·12	85	45	14·20	15·79	+1·59	1
α Ophiuchi	17	29	21·79	21·82	+0·03	77	21	4·56	4·24	−0·32	3
β Ophiuchi	17	37	32·62	32·67	+0·05	85	22	52·67	51·72	−0·95	2
μ Herculis	17	41	45·73	45·66	−0·07	62	12	29·67	29·10	−0·57	2
72 Ophiuchi	18	1	39·60	39·63	+0·03	80	27	7·67	6·71	−0·96	2
μ Sagittarii	18	6	35·11	35·15	+0·04	111	5	19·11	18·42	−0·69	3
η Serpentis	18	15	5·99	6·00	+0·01	92	55	41·84	43·43	+1·59	4
λ Sagittarii	18	20	33·86	33·84	−0·02	115	29	12·93	10·89	−2·04	5
σ Octantis	18	24	30·43	29·62	(−0·81)	179	16	30·02	29·92	(−0·10)	170
α Lyræ	18	32	52·52	52·47	−0·05	51	19	38·36	38·81	+0·45	3
β^1 Lyræ	18	45	38·95	38·90	−0·05	56	49	33·07	32·73	−0·34	1
ϵ Aquilæ	18	54	10·48	10·53	+0·05	75	5	37·11	36·18	−0·93	1
ζ Aquilæ	18	59	53·56	53·62	+0·06	76	18	49·25	49·95	+0·70	2
ω Aquilæ	19	12	10·96	10·99	+0·03	78	37	11·52	11·63	+0·11	3
δ Aquilæ	19	19	26·78	26·82	+0·04	87	7	23·56	23·78	+0·22	5
h^2 Sagittarii	19	29	24·13	24·16	+0·03	115	8	47·86	48·89	+1·03	3
γ Aquilæ	19	40	33·28	33·25	−0·03	79	40	41·47	40·88	−0·59	4
α Aquilæ	19	44	55·68	55·67	−0·01	81	26	51·19	49·64	−1·55	5
β Aquilæ	19	49	25·09	25·09	0·00	83	53	30·76	31·02	+0·26	5
θ Aquilæ	20	5	6·73	6·77	+0·04	91	10	34·88	34·64	−0·24	3

Name of Star.	*N.A.* R.A. h	m	s	Seconds of Cape R.A. s	Cape−*N.A.* s	*N.A.* N.P.D. °	′	″	Seconds of Cape N.P.D. ″	Cape−*N.A.* ″	No. of Cape Obs. N.P.D.
a^2 Capricorni	20	11	23·67	23·69	+0·02	102	54	56·35	56·52	+0·17	3
α Pavonis	20	16	8·67	8·77	(+0·10)	147	7	2·85	3·13	(+0·28)	3
ρ Capricorni	20	22	0·77	0·83	+0·06	108	12	32·87	32·69	−0·18	4
ϵ Delphini	20	27	28·74	28·78	+0·04	79	6	12·63	13·33	+0·70	2
α Cygni	20	37	20·43	20·44	+0·01	45	8	52·43	52·20	−0·23	1
‹Aquarii	20	41	10·68	10·72	+0·04	99	56	2·51	2·47	−0·04	3
32 Vulpeculæ	20	49	26·73	26·67	−0·06	62	23	53·20	54·03	+0·83	1
θ Capricorni	20	59	11·98	11·96	−0·02	107	42	30·73	31·51	+0·78	3
ζ Cygni	21	7	49·70	49·69	−0·01	60	15	53·06	52·48	−0·58	2
β Aquarii	21	25	14·38	14·42	+0·04	96	5	53·81	53·41	−0·40	7
ϵ Pegasi	21	38	17·56	17·49	−0·07	80	40	28·65	28·52	−0·13	3
16 Pegasi	21	47	36·17	36·11	−0·06	64	38	20·52	18·67	−1·85	3
α Aquarii	21	59	37·11	37·16	+0·05	90	54	8·34	7·75	−0·59	10
α Gruis	22	0	39·75	39·78	(+0·03)	137	32	28·64	27·97	(−0·67)	3
θ Aquarii	22	10	29·98	30·01	+0·03	98	22	49·35	49·04	−0·31	3
γ Aquarii	22	15	27·41	27·43	+0·02	91	59	28·73	28·98	+0·25	4
η Aquarii	22	29	11·30	11·34	+0·04	90	44	8·12	7·98	−0·14	7
ζ Pegasi	22	35	28·54	28·59	+0·05	79	47	40·98	40·96	−0·02	6
λ Aquarii	22	46	21·09	21·17	+0·08	98	13	3·44	3·80	+0·36	3
α Piscis Aust.	22	51	0·93	0·93	0·00	120	15	29·15	28·20	−0·95	6
α Pegasi	22	58	46·99	46·98	−0·01	75	26	24·26	24·10	−0·16	3

γ Piscium	23	10	56·60	56·60	0·00	87	22	24·54	23·79	−0·75	3
κ Piscium	23	20	46·81	46·83	+0·02	89	24	4·82	4·61	−0·21	9
ι Piscium	23	33	46·67	46·67	0·00	85	1	26·83	26·83	0·00	9
δ Sculptoris	23	42	40·37	40·32	−0·05	118	47	37·32	37·36	+0·04	3
ω Piscium	23	53	8·94	8·95	+0·01	83	48	4·23	3·51	−0·72	7

The large error in the *Nautical Almanac* for α *Centauri* is chiefly due to the proper motion used in the *Nautical Almanac*.

The mean N.P.D's of λ *Sagittarii* from the Greenwich Catalogues 1860, 1864, and 1872 corrected, are 115° 29′ 11″·75, 12″·94, and 10″·48, respectively. The Cape Catalogue for 1860 gives 115° 29′ 11″·55. The large discordance therefore does not appear to be mainly due to error in the Cape observations.

16 *Pegasi*. There is one very discordant observation included in the Cape mean result. If this observation were rejected, the Cape N.P.D. would be 64° 38′ 19″·40, with a difference of −1″·12 from the *Nautical Almanac*. The Greenwich results are accordant, but I can see no reason for doubting the Cape result, except to the extent mentioned.

χ *Leonis*. The Cape observations appear correct.

π *Virginis*. One of the observations was picked up through cloud. The N.P.D. appears to be about 4″ too small, and should probably be rejected.

The following are the corrections required by the *Nautical Almanac* Right Ascensions in order that they should agree with the Cape observations :—

R.A.			
h h	h h	h h	h h
0 to 6	6 to 12	12 to 18	18 to 24
s	s	s	s
+0·001	−0·005	−0·018	+0·010

The clock-errors at the Cape were determined from Right Ascensions based upon the Greenwich Fundamental Right Ascensions, and the above agreement is therefore no more than might fairly be expected; but these differences agree in sign with those which I obtained, when forming the Cape Catalogue for 1860, from a discussion of the observations made during the years 1856 to 1860. It is probable, therefore, that, although very small, these differences do not arise from mere chance errors of observation.

The refractions used for the reduction of the Cape observations have been computed from the *Tabulæ Regiomontanæ*; but no change has been made in the coefficient in passing through the zenith distance 85°. The barometer used has been the standard one of the Observatory. The thermometer is the one read for the temperature of the air and is exposed in a cage, with free circulation of air, before a southern window of the Transit-Circle room. The thermometer reads too high by 0°·55 F. To avoid mistakes, I thought it better to enter and reduce the observations with the readings uncorrected. The refractions used in the reductions are therefore those of the *Tabulæ Regiomontanæ* reduced in the ratio of

0·9988 to 1.

I have examined, from time to time, the accuracy with which the refractions thus computed represented the Cape observations, and have been satisfied upon the point.*

The residual errors given in the present paper will, however, afford additional information on the point.

The latitude of the Observatory adopted in the formation of the Catalogue is

°	′	″	
33	56	3·41	South.

If $33^\circ\ 56'\ 3''{\cdot}41 - x$ is assumed to be the true south latitude and Tab. refra. $(1+y)$ the true refraction, the following are the values of x which result from a discussion of all the observations above and below the Pole contained in the Catalogue.

* *See* Cape Catalogue, 1860, Introduction; Cape Observations, 1871, 1872, and 1873 and 1874.

Mean N.P.D.	
175° to 180°	$x = +0''.09 + 87\,y.$
170°	$x = +0''.16 + 95\,y.$
165°	$x = -0''.05 + 109\,y.$
160°	$x = -0''.24 + 136\,y.$
154°	$x = -0''.34 + 213\,y.$
150°	$x = +0''.05 + 366\,y.$

The corrections which x and y require must therefore be very small.

The refractions of Bessel's *Tabulæ Regiomontanæ* appear to represent the Cape observations in *mean* results with considerable accuracy. So far as these colatitude equations are alone concerned, the agreement between the different values of x would be slightly improved if the correction for the index error of the thermometer had been applied, or if y had been put equal to 0°.001. The changes thus introduced would, however, be unimportant, and it would appear, from what follows, very doubtful whether these changes are really required. I have, at all events, not considered it necessary to introduce the changes, and the North Polar Distances of the Cape Catalogue are therefore, as before stated, based on Bessel's mean refractions diminished in the ratio of

0·9988 to 1.

If we divide the corrections to the North Polar Distances of the *Nautical Almanac* into four groups depending upon N.P.D., we have the following corrections:—

	N.P.D. 40° to 60°	N.P.D. 60° to 90°	N.P.D. 90° to 105°	N.P.D. 105° to 124°
Correction =	−0″.33	−0″.35	−0″.15	−0″.40

These corrections are all small and there does not appear to be any systematic change in them depending upon the N.P.D. of the group. This is a further proof of the substantial accuracy of the refractions adopted, and we are justified in forming a general mean result. We have therefore for the mean result—

N.A. N.P.D. = Cape N.P.D. + 0″.31.

Next, in order to test whether there is any large outstanding correction depending upon the meteorological elements, I shall give the corrections required by the *Nautical Almanac* North Polar Distances for groups of six hours of Right Ascension.

	From	h	to	h	h	to	h	h	to	h	h	to	h
		0	to	6	6	to	12	12	to	18	18	to	24
Correction	=			−0″·55			−0″·42			+0″·08			−0″·25

Applying to these corrections the general mean correction −0″·31, we have

	From	h	to	h	h	to	h	h	to	h	h	to	h
		0	to	6	6	to	12	12	to	18	18	to	24
Correction	=			−0″·24			−0″·11			+0″·39			+0″·06

The changes in these corrections are systematic, and it appears that the complete reversion of the seasons at the northern and southern Observatories is not quite accurately allowed for in our refraction tables. The observations 0^h to 6^h R.A. were made during the dry seasons at the Cape, and the tabular refractions used are apparently relatively too large. The observations from 12^h to 18^h were made during the wet seasons at the Cape, and the tabular refractions used are apparently relatively too small. But the changes in humidity at the Cape are simultaneous with considerable changes in mean temperature.

There cannot, I should conceive, be any doubt about the systematic character of the small discordance to which I have called attention; but there will probably be differences of opinion respecting the cause.

Some astronomers will probably consider it to arise from an imperfect correction for changes of temperature, whilst others may consider it due to the neglect of any alteration of refraction as dependent upon moisture. My own opinion is that the last explanation is likely to be the true one. I was led to a similar result many years ago, and I hope before long to be able to investigate the question of the effects of humidity upon refraction.

Ephemeris for finding the Positions of the Satellites of Uranus, 1880.

By A. Marth, Esq.

Angle of position, p_o, of the major axes, major and minor semi-axes, a and b, of the apparent ellipses described by the satellites, and latitude of the Earth above the plane of their orbits.

Greenwich Noon.		*Ariel.*		*Umbriel.*		*Titania.*		*Oberon.*		Lat. of Earth.
	p_o	a	b	a	b	a	b	a	b	
1880.	°	″	″	″	″	″	″	″	″	°
Jan. 15	14·03	15·05	1·88	20·96	2·60	34·38	4·25	45·98	5·72	−7·16
25	13·97	15·14	1·97	21·09	2·74	34·60	4·49	46·27	6·01	7·46
Feb. 4	13·91	15·21	2·07	21·19	2·89	34·76	4·74	46·49	6·33	−7·82
14	13·84	15·26	2·18	21·26	3·04	34·87	4·99	46·63	6·67	8·23
24	13·76	15·28	2·30	21·29	3·20	34·92	5·25	46·69	7·03	8·66

Greenwich Noon. 1880.	p_o	*Ariel.* a	b	*Umbriel.* a	b	*Titania.* a	b	*Oberon.* a	b	Lat. of Earth.
	°	"	"	"	"	"	"	"	"	°
Mar. 5	13·68	15·27	2·41	21·28	3·36	34·90	5·51	46·67	7·37	−9·09
15	13·61	15·24	2·52	21·23	3·51	34·82	5·75	46·57	7·69	9·51
25	13·54	15·18	2·61	21·15	3·63	34·69	5·96	46·39	7·97	9·89
Apr. 4	13·47	15·10	2·68	21·04	3·73	34·51	6·12	46·14	8·19	−10·22
14	13·42	15·00	2·73	20·90	3·81	34·28	6·24	45 84	8·35	10·49
24	13·38	14·89	2·76	20·74	3·85	34·02	6·31	45·49	8·44	10·69
May 4	13·36	14·76	2·77	20·56	3·85	33·73	6·32	45·11	8·45	−10·80
14	13·36	14·63	2·75	20·38	3·83	33·43	6·28	44·71	8·39	10·82
24	13·37	14·50	2·71	20·20	3·77	33·13	6·18	44·30	8·27	−10·76

Longitudes of the satellites in their orbits, reckoned from the points where they are at their greatest northern elongations.

Greenwich Noon. 1880.	*Ariel.* long.	diff.	*Umbriel.* long.	diff.	*Titania.* long.	diff.	*Oberon.* long.	diff.
	°	°	°	°	°	°	°	°
Jan. 15	346·86		265·20		247·99		102·53	
		1428·40		868·69		413·48		267·35
25	335·26		53·89		301·47		9·88	
		·37		·67		·47		·35
Feb. 4	323·63		202·56		354·94		277·23	
		·34		·66		·47		·34
14	311·97		351·22		48·41		184·57	
		·31		·64		·46		·34
24	300·28		139·86		101·87		91·91	
		·29		·62		·45		·33
Mar. 5	288·57		288·48		155·32		359·24	
		·26		·61		·44		·33
15	276·83		77·09		208·76		266·57	
		·25		·60		·45		·33
25	265·08		225·69		262·21		173·90	
		·23		·60		·44		·34
Apr. 4	253·31		14·29		315·65		81·24	
		·23		·60		·45		·34
14	241·54		162·89		9·10		348·58	
		·22		·60		·46		·35
24	229·76		311·49		62·56		255·93	
		·22		·60		·47		·36
May 4	217·98		100·09		116·03		163·29	
		·23		·61		·48		·38
14	206·21		248·70		169·51		70·67	
		1428·23		868·62		413·49		267·38
24	194·44		37·32		223·00		338·05	

These values are to be interpolated for the times for which the positions of the satellites are required. The position angles, p, and distances, s, are then found by means of the equations,

$$s \sin (p_o - p) = b \sin \text{long.}$$
$$s \cos (p_o - p) = a \cos \text{long.}$$

Observations of Comet Palisa made with the Merz Equatoreal of the Collegio Romano. By Prof. Pietro Tacchini.

Data.	Tempo medio di Roma.	$\alpha\mathcal{C}-\alpha*$	$\delta\mathcal{C}-\delta*$	α apparente $\mathcal{C}$	δ apparente $\mathcal{C}$	Stelle di confronto.	Posizione delle stelle di confronto (Equinozio medio 1° Gennaio 1879).	Numero dei confronti.	Osservatore.	Numero di ordine.	Osservazioni sulla cometa.
1879.	h m s	m s	′ ″	h m s	° ′ ″		h m s ° ′ ″				
3 Sett.	8 18 5	−4 44·40	− 0 32·0	11 28 38·59	+45 48 54·4	½ (22088 Lal.+1813 Groom.).	α 11 33 21·27 δ +45 49 37·9	1	T.	1	Nucleo piccolo e debole.
6 ,,	8 13 25	+4 45·26	+ 1 38·1	11 49 2·12	44 21 25·6	165 Hora XI. Piazzi.	11 44 15·12 44 19 58·8	5	T.	2	
7 ,,	8 21 55	−0 10·30	+ 6 5·3	11 55 49·18	43 48 52·2	4057 (C. of B.A.A.).	11 55 57·82 43 42 57·4	7	T.	3	Diametro 119″.
,,	7 42 42	−0 51·18	+ 6 46·4	12 2 21·44	43 15 58·7	22799 Lalande.	12 3 10·93 43 9 23·4	4	T.	4	
9 ,,	7 51 34	+1 3·65	− 9 51·6	12 9 1·05	42 39 47·9	140 H. 12 Weisse.	12 7 56·35 42 49 50·5	3	M.	5	
10 ,,	8 44 37	+0 40·70	− 8 48·1	12 15 56·41	42 0 22·4	294 H. 12 Weisse.	12 15 14·06 42 9 21·5	2	M.	6	La cometa passò colla nebulosità sopra una stella di 10° gr. senza alterarne lo splendore.
12 ,,	8 21 8	−1 9·50	+19 30·6	12 28 48·42	40 40 24·8	½ (613 H. 12 Weisse +23557 Lalande).	12 29 56·26 40 21 5·2	1	M.	7	
13 ,,	8 36 20	+2 13·80	− 1 24·6	12 35 14·26	39 57 20·7	23646 Lalande.	12 32 58·81 39 58 56·3	2	M.	8	
14 ,,	9 7 44	−2 17·61	+10 19·2	12 41 40·44	39 11 48·0	23930 Lalande.	12 43 56·41 39 1 39·5	3	M.	9	
18 ,,	7 49 14	−3 54·45	− 3 8·5	13 5 40·63	36 1 51·6	143 H. 13 Weisse.	13 9 33·48 36 5 10·7	4	M.	10	
19 ,,	8 6 48	+1 35·83	+20 15·8	13 11 39·76	35 9 33·2	156 H. 13 Weisse.	13 10 2·24 34 49 28·9	4	M.	11	
22 ,,	7 46 43	+0 8·50	+18 11·9	13 28 29·44	32 28 16·5	2360 Z. 32° Arg.	13 28 19·29 32 10 15·1	2	M.	12	
24 ,,	7 44 32	−3 45·50	+ 7 51·6	13 39 18·35	30 35 33·2	886 H. 13 Weisse.	13 43 2·19 30 27 51·0	3	M.	13	
2 Ott.	6 56 35	+0 30·26	−11 54·8	14 19 50·56	22 37 19·7	½ (361 H. 14 Weisse+ 4679 H. 14 Rümker).	14 17 48·09 22 49 24·0	7	T.	14	
3 ,,	7 12 16	+2 4·05	− 1 39·2	14 22 51·33	31 36 42·4	2651 Z. 21° Arg.	14 20 45·70 21 38 31·0	6	T.	15	Diametro 109″.
5 ,,	7 9 7	+1 48·70	− 9 20·8	14 31 29·79	19 35 12·6	½ (26620 Lalande+606 H. 14 Weisse).	14 29 39·27 19 44 42·7	4	T.	16	
5 ,,	7 9 7	+1 37·72	−11 43·5	14 31 29·94	19 35 14·3	26626 Lalande.	14 29 50·40 19 47 7·1	4	T.	17	
6 ,,	7 35 24	−0 36·02	+ 8 40·1	14 35 45·68	18 33 5·5	746 H. 14 Weisse.	14 36 19·62 18 24 33·8	4	T.	18	
6 ,,	7 35 24	−1 40·17	− 1 46·8	14 35 46·23	18 33 20·4	772 H. 14 Weisse.	14 37 24·32 18 35 15·6	4	T.	19	
7 ,,	6 47 58	+0 7·00	+ 5 13·4	14 39 44·73	17 33 46·8	4873 (C. of B.A.A.).	14 39 35·87 17 28 42·6	5	T.	20	
7 ,,	7 18 46	+0 12·36	+ 4 9·4	14 39 58·09	17 32 33·8	[illegible]	14 39 35·87 17 28 42·6	5	T.	20	Diametro 103″.

8	,,	6 47 58	+1 1·82	− 6 1·2	14 43 47·09	16 32 55·1	26982 Lalande.		14 42 43·39	16 39 5·5	5	T.	21
8	,,	7 6 21	+1 5·34	− 6 45·0	14 43 50·61	16 32 11·3	,, ,,		14 42 43·39	16 39 5·5	5	T.	21
9	,,	6 47 40	+0 28·02	− 5 38·6	14 47 45·03	15 32 2·1	27114 ,,		14 47 15·11	15 37 49·9	4	T.	22
9	,,	6 47 40	−1 36·52	+ 3 59·4	14 47 44·04	15 32 6·4	27167 ,,		14 49 19·06	15 28 16·2	4	T.	23
9	,,	7 30 48	+0 35·15	− 7 9·1	14 47 52·16	15 30 31·6	27114 ,,		14 47 15·11	15 37 49·9	4	T.	22
9	,,	7 30 48	−1 29·87	+ 2 20·9	14 47 51·09	15 30 28·0	27167 ,,		14 49 19·06	15 28 16·2	4	T.	23
10	,,	6 41 30	−0 58·50	+ 0 39·1	14 51 36·25	14 31 56·1	27283 ,,		14 52 32·83	14 31 26·4	5	T.	24
10	,,	7 4 45	−0 54·58	− 0 12·3	14 51 40·17	14 31 4·7	27283 ,,		14 52 32·83	14 31 26·4	5	T.	24
11	,,	7 7 50	−2 45·22	− 3 46·7	14 55 29·92	13 30 56·6	1079 Weisse H. 14		14 58 13·20	13 34 52·9	6	T.	25
12	,,	6 44 18	−0 29·77	+ 7 8·7	14 59 9·74	12 32 31·3	1100 ,, ,,		14 59 37·55	12 25 33·3	3	T.	26
12	,,	6 44 18	−0 35·43	+13 6·2	14 59 9·61	12 32 40·2	1102 ,, ,,		14 59 43·08	12 19 43·7	3	T.	27
12	,,	7 11 20	−0 26·20	+ 5 57·2	14 59 13·31	12 31 20·8	1100 ,, ,,		14 59 37·55	12 25 33·3	3	T.	26
12	,,	7 11 20	−0 31·87	+11 56·1	14 59 13·17	12 31 30·1	1102 ,, ,,		14 59 43·08	12 19 43·7	3	T.	27
13	,,	6 49 54	+1 54·74	+ 1 11·5	15 2 51·03	11 33 3·9	1125 ,, ,,		15 0 54·29	11 32 2·2	4	T.	28
13	,,	6 49 54	+0 27·60	+10 26·2	15 2 50·45	11 33 7·6	1162 ,, ,,		15 2 30·85*	11 22 51·2	4	T.	29
13	,,	7 16 25	+1 58·80	+ 0 10·8	15 2 55·09	11 32 3·2	1125 ,, ,,		15 0 54·29	11 32 2·2	4	T.	28
13	,,	7 16 25	+0 31·82	+ 9 26·4	15 2 54·69	11 32 7·8	1162 ,, ,,		15 2 30·85	11 22 51·2	4	T.	29
14	,,	6 41 25	+0 26·85	− 6 16·8	15 6 27·01	10 33 56·5	27692 Lalande.		15 5 58·17	10 40 23·1	6	T.	30
14	,,	6 41 25	+0 35·97	− 0 51·2	15 6 25·97	10 33 56·9	27684 ,,		15 5 48·01	10 34 57·9	6	T.	31
14	,,	6 41 25	−3 20·60	− 0 22·0	15 6 26·15	10 34 10·0	27814 ,,		15 9 44·76	10 34 41·8	6	T.	32
17	,,	6 33 15	+0 7·72	− 3 32·5	15 16 49·09	7 42 49·0	270 H. 15 Weisse.		15 16 39·33	7 46 30·7	5	T.	33
17	,,	6 54 17	+0 10·54	− 4 9·2	15 16 51·91	7 42 12·3	270 ,, ,,		15 16 39·33	7 46 30·7	5	T.	33
19	,,	6 33 45	+1 1·76	− 7 11·8	15 23 28·91	5 51 13·5	391 ,, ,,		15 22 25·10	5 58 34·3	4	T.	34
19	,,	6 53 57	−0 57·48	+ 9 36·4	15 23 32·05	5 50 15·4	425 ,, ,,		15 24 27·48	5 40 47·6	4	T.	35
22	,,	6 37 47	−0 55·75	+11 39·2	15 33 15·27	3 8 35·4	624 ,, ,,		15 34 8·94	+2 57 4·6	4	T.	36

* La stella 29 che è la 1162 H. 14 Weisse deve essere diminuita probabilmente di 10ˢ.
Le posizioni della cometa devono essere corrette di parallasse.
La lettera T. indica Tacchini ; la lettera M. indica Millosevich ; le riduzioni si fecero da quest' ultimo.

Roma, Ottobre 1879

Observations of Comet Hartwig made with the Merz Equatoreal of the Collegio Romano. By Prof. Pietro Tacchini.

Data. 1879.	Tempo medio di Roma. h m s	$\alpha\delta - \alpha*$ m s	$\delta\delta - \delta*$ ′ ″	α apparente δ h m s	δ apparente δ ° ′ ″	Stelle di confronto.	Numero dei confronti.	Osservatore.	Numero di ordine.	Osservazioni sulla cometa.
9 Sett.	8 28 40	−2 33·60	−11 37·5	13 46 50·94	+37 28 27·5	25625 Lalande	3	M.	1	Debolissima; forma ovale.
11 „	8 3 4	+0 13·55	− 2 25·4	13 52 4·11	34 59 1·6	1122 H. 13 Weisse.	4	M.	2	
11 „	8 38 43	+0 17·77	− 4 25·6	13 52 8·33	34 57 1·4	1122 H. 13 Weisse.	2	M.	2	
12 „	9 18 19	−0 31·90	− 9 32·1	13 54 33·09	33 42 48·4	1186 H. 13 Weisse.	1	M.	3	
13 „	7 53 28	−0 4·20	+ 8 8·5	13 56 42·88	32 36 36·9	2422 Z. 32° Arg.	4	M.	4	[ad osservare.
14 „	8 28 16	−2 14·42	+ 0 66·0	13 58 51·80	31 26 51·9	4694 (C. of B.A.A.)	4	M.	5	Oggetto difficile

Equinozio medio 1° Gennaio 1879.

Stelle di confronto.

		h	m	s		°	′	″
1	α	13	49	22·70	δ	+37	40	11·0
2			51	48·84		35	1	33·6
3			55	3·26		33	52	27·1
4			56	45·35		32	28	35·1
5			61	4·48		31	25	52·7

Le posizioni della cometa non sono corrette di parallasse. La lettera M significa Millosevich.

Roma, Ottobre 1879.

On the Correction for Personality required by the Observations of the Moon made with the Greenwich Transit-Circle.

By E. Neison, Esq.

During the course of my investigation of the corrections required by the theory embodied in Hansen's Lunar Tables in order to bring the tabular place of the Moon into accord with observation, I have most carefully compared the corrected theory with the observations of the Moon made with the Greenwich Transit-Circle. The result of the comparison is decidedly satisfactory when the error of the Moon's mean longitude is deduced separately for each year, showing that the theory of the terms of short period has been rendered accurate. It remains to compare the errors of mean longitude deduced for each year from the observations, with the view of deducing the requisite corrections to the theory of the terms of long period. This portion of the investigation has not yet been completed, though the discordance between theory and observation has been already materially reduced by the introduction of several terms of long period, whose existence has been discovered by my theoretical researches. During this part of the investigation I have discovered several sudden changes in the error of mean longitude, which were too sudden to arise from any defect in the theory, and too large and too marked to be merely accidental. Lately, by a rigorous examination of the observations, I have convinced myself that these sudden changes do not arise from any imperfections in the theory, but must arise from some cause within the Observatory itself.

The observations of the Moon with the Transit-Circle at Greenwich appear to be, as far as possible, equally divided amongst four of the Assistants, though occasionally observations are made by others. As a rule, however, about five-sixths of the total number of observations are made by four of the Assistants. It might therefore be very fairly assumed that the mean of the observations made by these four observers would be to all intents independent of any systematic error due to personality on their part, as it is known that such personality is not large in any one case. Therefore, so far as I am aware, hitherto everyone who has investigated the theory of the Moon has assumed that the error of mean longitude derived from a year's observation might be held to be independent of any personality on the part of the observers, and to be comparable with the error deduced from the observations of any other year.

Some time back it was suggested to me that the personal error of the Greenwich observers might not be constant, and that therefore the mean error derived from their observations might vary from year to year. From some notes I had of a paper by

Mr. Dunkin, entitled 'On Personality in observing Transits of the Limbs of the Moon" (*Monthly Notices*, 1869, vol. xxix. page 259), I was aware that the personal equations of the lunar observers were tolerably constant and in no case large, so that it did not seem likely that any such variation would occur. To satisfy myself that this view was correct, I compared the mean of all the observers for each year with the mean for the entire period of six years, using the data given in my notes of Mr. Dunkin's paper. The result was entirely satisfactory, the corrections to be applied to each year's observation to reduce them to the same standard being as under:—

	s
1863 =	−0·010
1864 =	+0·003
1865 =	−0·010
1866 =	+0·010
1867 =	0·000
1868 =	+0·008

These quantities were smaller than the probable error of their determination, and were themselves so small that they could be neglected.

When, therefore, my investigations showed that these variations, or rather sudden changes, in the error of mean longitude were probably due to some cause within the Observatory itself, it was difficult to imagine what could be the real source of these variations. There had been no change in the method of reduction, so that it could not arise from that cause. Further investigation showed that the observations with the altazimuth were affected by the same sudden changes, though to a modified amount; it was evident, therefore, that the origin of these changes was not in the instrument itself. Everything pointed to its arising from some effect of the personality on the part of the observers. Yet this conclusion seemed negatived by the results already referred to, which I had obtained some years previously. I resolved, however, to investigate anew this question.

I knew that in his paper in the xxix. volume of the *Monthly Notices*, Mr. Dunkin had arrived at the conclusion that observers had a very different personal equation for each limb of the Moon, but that for each limb this personal equation was almost constant. My first step was, therefore, to examine Mr. Dunkin's paper to see what light it might throw on this subject. It appeared that Mr. Dunkin had based his investigation on the assumption (*loc. cit.* page 263) that "the mean tabular errors are assumed to be constant throughout the mean lunation." It is now known that this assumption is not a permissible one, for the tabular

errors are not constant throughout the mean lunation; but that, owing to imperfections in the theory, they are systematically different before and after Full Moon. My own investigations have shown that this error varies during the year to such an extent that the difference in the Moon's tabular error before and after opposition will vary from nearly 8″ in one part of the year to less than 1″ in another part. For this reason, therefore, the conclusions which have been arrived at by Mr. Dunkin in his paper will require material modification.

The data which has served as the basis of my investigation has been the Greenwich Transit-Circle observations of the Moon made during the fourteen years between 1863 and 1876. Each Assistant's observations were separately extracted from the different volumes of *Greenwich Astronomical Results* and discussed by themselves, the observations of the I and II limbs being kept separate. As far as possible without separately calculating the corrections for each observation, the main errors of short period in the theory were eliminated, and it was assumed that the smaller errors would practically destroy each other in the mean result. Next, the results obtained for each observer were referred to one observer, who was taken as the standard. For this purpose Mr. Criswick was selected, for the reason that his observations alone extended throughout the entire period of fourteen years. Fortunately it also happens that his observations are the most numerous.

In this manner an approximate value of the personal equation of each observer was obtained for each year. The results were perfectly analogous to the similar results given by Mr. Dunkin, in his paper already quoted, and they clearly showed that, not only was the personal equation of each observer small, but that it was nearly constant in each case. Much of the deviation from the mean could be traced to the effect of the errors in the theory which had been left to correct themselves. The result for each year was weighted in proportion to the number of observations on which it rested, some slight weight being also given to the equable distribution of the observations. Then, from the different results for each of the fourteen years, the following values were obtained for the mean personal equation of the observers:—

		For I Limb.		For II Limb.	
		s	Weight.	s	Weight.
Dunkin	− Criswick = D − C =	−0·012	4	−0·032	3
Ellis	− Criswick = E − C =	−0·106	9	−0·065	7
J. Carpenter	− Criswick = JC − C =	−0·125	8	−0·038	6
Lynn	− Criswick = L − C =	+0·034	4	+0·058	3
A. Downing	− Criswick = AD − C =	+0·007	2	+0·109	2
Thackeray	− Criswick = T − C =	+0·040	1	+0·093	½

Substituting these values in the original expressions, it was found that they well satisfied them, the residuals being reduced to small quantities, in the greater number of cases less than $^{s}\cdot020$.

The next step is to refer all the observations to some standard which will be more independent of the variations due to the imperfect elimination of the errors of the lunar tables and the chance errors of observation than can be the case with the mean of the observations which any selected observer may make in a year. It is evident that, by merely referring the results to the mean of the observations obtained by the selected observer in the year, the entire deviation of that mean from the true value of the personal equation of the observer is thrown on all the values for the personal equations of the other observers as determined from the observations of the year, creating in them merely fictitious variations. If it were possible to determine the absolute personal equation of Mr. Criswick, it would be possible to completely eliminate from the observations the effect of the personalities of the observers. This cannot be done from the Greenwich observations alone. Some standard must be assumed, therefore, and it is immaterial what standard be chosen in so far as the accuracy of the results is concerned. The most convenient standard would be to assume that the mean of all the personal equations of the seven observers is free from error. However, as the materials for determining the personal equation of two of the observers, Messrs. Downing and Thackeray, are very imperfect, it has been assumed that the sum of the personal equations of Messrs. Dunkin, Ellis, Criswick, J. Carpenter, and Lynn will be zero, and the mean of their observations correspond to the true place of the Moon.

The observations of each observer for each year were then referred to the mean error for the year derived from all the observations, so as to eliminate as far as possible the outstanding errors. The total number of observations was divided into four groups, 1863–69; 1870–72; 1873–74; 1875–76; in each of which the main observations of the Moon were made by four Assistants. Each of these groups was marked out from the others by the fact that in it the place of one of the observers of the preceding or following group was taken by another observer. It was then assumed that each of these groups needed a correction, a_1 a_2 a_3 a_4 respectively, to bring the mean of the observations in the group into accord with the selected standard. Then these corrections were determined by equating the mean results of the three observers who observed in both groups, after correcting each for proper personal equation.

In this manner the following values were obtained for the personal equations of the different observers for each limb of the Moon. The probable errors were obtained from the residuals.

	I Limb.		II Limb.	
	s	s	s	s
Dunkin	= +0·025	±0·012	+0·004	±0·014
Ellis	= −0·060	±0·009	−0·041	±0·010
Criswick	= +0·045	±0·008	+0·026	±0·009
J. Carpenter	= −0·074	±0·010	−0·014	±0·012
Lynn	= +0·075	±0·015	+0·066	±0·020
A. Downing	= +0·006	±0·022	+0·132	±0·026
Thackeray	= +0·063	±0·025	+0·183	±0·050

These personal equations are unmistakably real, as is clearly shown by the small probable errors, which show how small are the outstanding residuals which they leave. Where the same four observers have been engaged, and where there can be no uncertainty as to the values of the quantities a_1, a_2, a_3, a_4 to interfere with the accuracy of the results, the differences between the mean of all observers and the mean of each are remarkably constant and uniform, showing clearly that they are due to real personal equations, and not merely to outstanding errors. Moreover, these personal equations are quantities whose variations must be due either to purely accidental errors which may have remained uneliminated, or to a real change in the personal equation of the observer. There seems little indication of the presence of any real change. Therefore the variations are presumably accidental, and of the nature to which may be most safely applied the theory of probable errors.

Owing to the much smaller number of observations, and the shorter period over which they extend, there must be a considerable uncertainty as to the accuracy of the values which have been assigned to the personal equations of Messrs. Downing and Thackeray, and especially of the latter. This will, of course, disappear to all probability when the investigation can be extended to the observations which have been made during the years 1877, 1878, and 1879. I believe, however, that the true values of the personal equations of these observers will be found to be included within the limits of the probable errors assigned to them.

The consideration of these personal equations leads to a very important result. Of the four observers—Messrs. Dunkin, Ellis, J. Carpenter, and Criswick—who observed the Moon from 1863 to the end of 1869, no less than three of them—the three first—were replaced by other observers during the five years 1870–74. But whereas the three retiring observers had personal equations whose mean value was largely negative, they have been succeeded by three observers whose personal equations are all largely positive. This change of observers has therefore introduced a considerable increase in the mean tabular error of the Moon which has no real existence. Each replacement of one observer by

another—a change which has practically come into operation at the beginning of a year—has been accompanied by a sudden increase in the tabular error of the Moon, an increase which has no foundation in fact. Before, therefore, the errors in the Moon's mean longitude can be properly investigated from observation, it is necessary to remove these fictitious increases and reduce the entire series of observations to one systematic standard. From the values which have been determined for the personal equations of the seven observers, it is easy to calculate the correction which should be applied to each year to reduce the errors in the Moon's Right Ascension to a uniform standard. They are—

	I Limb.	II Limb.	Centre.
	s ″	s ″	s ″
1863	+0·001 = +0·015	−0·002 = −0·030	0·000 = 0·000
1864	+0·017 = +0·255	−0·003 = −0·045	+0·009 = +0·135
1865	+0·007 = +0·105	−0·010 = −0·150	0·000 = 0·000
1866	+0·016 = +0·240	−0·006 = −0·090	+0·007 = +0·105
1867	+0·015 = +0·225	−0·009 = −0·135	+0·007 = +0·105
1868	+0·020 = +0·300	−0·008 = −0·120	+0·008 = +0·120
1869	+0·020 = +0·300	−0·006 = −0·090	+0·007 = +0·105
1870	+0·013 = +0·195	−0·012 = −0·180	+0·002 = +0·030
1871	−0·011 = −0·165	−0·020 = −0·300	−0·018 = −0·270
1872	−0·004 = −0·060	−0·017 = −0·255	−0·009 = −0·135
1873	−0·014 = −0·210	−0·040 = −0·600	−0·025 = −0·375
1874	−0·005 = −0·075	−0·054 = −0·810	−0·029 = −0·435
1875	−0·041 = −0·615	−0·081 = −1·215	−0·057 = −0·855
1876	−0·047 = −0·705	−0·079 = −1·185	−0·058 = −0·870

These results clearly show the unexpected effect of the change in the observers at Greenwich, there being a change of 1″ in the mean error of longitude in the short space of five years. The variation is of such unexpected magnitude, that it will be necessary to more rigidly examine the observation, correcting each individual observation for the errors of short period in the lunar theory, and taking into consideration the observations for the years 1877 and 1878. For this purpose, in my discussion of these observations, I shall have to introduce seven more undetermined coefficients to represent the personal equations of the seven Greenwich observers, and to be determined simultaneously with the errors in the mean longitude and coefficients of long period employed by Hansen in his Tables. In the meantime it appears to be important to make known the unexpected result of the present investigation.

Note on the Correction to the Mean Longitude of Hansen's Lunar Tables. By Prof. S. Newcomb.

In vol. xxxix. No. 9, of the *Monthly Notices* Mr. Lynn shows that the correction to the mean longitude of the Moon has apparently diminished during the last two years, and concludes that the mean error is probably still diminishing. I wish to call attention to the fact that the fluctuations in the course of the error may be accounted for by the seventeen-year term due to the action of *Jupiter*, computed by Mr. Neison, namely—

$$\delta l = 2''.2 \sin (2\varpi - 2J),$$

ϖ being the longitude of the Moon's perigee and J the mean longitude of *Jupiter*.* Substituting for ϖ and J their values in terms of the time, the correction becomes

$$\delta l = 2''.2 \sin \{293^\circ + 20^\circ.66\,(t - 1870^\circ.5)\}.$$

The dates of its maxima and minima are as follows :—

Maximum, of $+2''.2$	1860·2,	1877·6.
Minimum, of $-2''.2$	1868·9,	1886·3.

It is therefore to be expected that the positive error of the Tables would reach a minimum about 1878·0.

I have taken the corrections to Hansen's mean longitude given in my *Researches on the Motion of the Moon*, p. 268, interpolated them to the middle of each year from 1876 to 1885, and applied Mr. Neison's inequality. The results are :—

Year.	Long Period Correction.	Neison's Correction.	Sum.
	"	"	"
1876·5	− 9·4	+2·0	− 7·4
77·5	− 9·9	+2·2	− 7·7
78·5	−10·4	+2·1	− 8·3
79·5	−10·9	+1·7	− 9·2
80·5	−11·5	+1·1	−10·4
81·5	−12·0	+0·3	−11·7
82·5	−12·6	−0·4	−13·0
83·5	−13·2	−1·1	−14·3
84·5	−13·8	−1·7	−15·5
85·5	−14·4	−2·1	−16·5

* See *Monthly Notices*, vol. xxxvii. pp. 359 and 428.

Mr. Lynn's results for 1878 were:—

From Meridian observations	$-8''.23$
„ Altazimuth „	$-7''.48$

They are as nearly accordant with the empirical theory as could be expected. The errors in 1876 are apparently $2''$ greater than theory. This may be due in part to inequalities not yet discovered, but is more likely to arise from systematic errors of a personal character in noting the times of transit of the Moon's limb. For several years preceding 1876 the Moon's R.A. as observed at Greenwich and Washington was some $1''$ or $2''$ greater than that derived from occultations, and from the meridian observations to other Observatories. Hence arose the constant difference between the corrections for 1875·0 found by Captain Tupman from observations at a number of Observatories and by myself from Greenwich and Washington alone. The occultations seem to show that the constant error was in my own results.

On the whole, I do not yet see any good reason to believe that the course of the errors during the next six years will be materially different from that above given. It would be a matter of interest if the few Observatories where the Moon is systematically observed would, after the end of each year, publish the mean correction to the Moon's longitude derived from the observations of the year.

On Recent Changes in the Mean Error of Longitude of Hansen's Lunar Tables.

By W. T. Lynn, B.A.

The critical point apparently reached in the mean error of longitude of the Moon, as assigned by Hansen's Tables, has led me to examine its circumstances a little more minutely than in my previous paper printed in the last *Supplementary Notice*; and, by the permission of the Astronomer Royal, I beg to offer the Society the following results of that examination.

It will have been noticed that the diminution of the error in 1878, to which I called attention as above, is shown by the observations made both with the meridian and altazimuth instruments. But in what follows I have discussed the altazimuth observations only, which are not only more numerous, but distributed through a larger part of each lunation than those made with the Transit-Circle.

My previous paper left it doubtful whether the turning point was in the year 1876 or 1877. I have now compared the mean error of longitude from the altazimuth observations in 1877,

which are 182 in number, and find it to be $+8''\cdot25$. (I may take the opportunity of mentioning that I detected a mistake in the result of the observation as printed (and shortly to be published) on February 26 for that year, when the error in longitude should be $+10''\cdot90$ instead of $+11''\cdot79$.) As this mean error was $+9''\cdot31$ in 1876, it is evident that it had reached a *maximum* in that year.

Now, for the purpose of ascertaining what the amounts of fluctuation of the error in the course of separate years were, I have put together the number of days in 1877 and 1878 in which the error of longitude was contained between each pair of consecutive seconds of its whole range. The following Table exhibits the result of that comparison :—

Error of Longitude.				No. of Days.	
	"		"	in 1877.	in 1878.
Between	−4	and	−3	2	0
„	−3	„	−2	0	1
„	−2	„	−1	0	3
„	−1	„	0	1	2
„	0	„	1	2	4
„	1	„	2	5	7
„	2	„	3	9	3
„	3	„	4	7	7
„	4	„	5	15	10
„	5	„	6	10	14
„	6	„	7	18	18
„	7	„	8	14	17
„	8	„	9	17	20
„	9	„	10	19	17
„	10	„	11	12	13
„	11	„	12	22	9
„	12	„	13	11	7
„	13	„	14	11	1
„	14	„	15	2	3
„	15	„	16	2	1
„	16	„	17	0	2
„	17	„	18	1	1
„	18	„	19	1	1
„	19	„	20	0	0
„	20	„	21	1	0

It results from this comparison that in 1877 the proportion 0·70, and in 1878 the proportion 0·73 of the whole of the errors

were contained between the limits $+4''$ and $+12''$; also that in neither was there more than a single observation, the error from which was included between two seconds of which the smallest was $+17''$.

In 1878, it will have been remarked that the number of altazimuth observations is considerably under the average, and the same will undoubtedly be the case for the current year also, the state of the sky for more than a year past having been very unfavourable for observations. An examination of the observations hitherto made during 1879 (embracing, of course, now by far the largest part of the year) shows* that the mean error in longitude is larger than in 1878, and about the same as in 1877; also that it has been increasing during the year, and that the mean value for the first three quarters (January to September) is about $+8''.9$.

I may mention that some time ago I compared the mean error of longitude for several years as resulting from the observations made in the different quarters of each lunation. In no case did I find any appreciable difference in the mean error for the first and second, or for the third and fourth quarters of each of different lunations. There was, indeed, a decided difference between the mean error in the first and second *halves* of the lunation, or the error from observations made before and after the Full Moon. But this may, of course, arise in great measure from the difference in the method of observing the first and the second limb of the Moon respectively; on which there is a well-known paper by Mr. Dunkin in the *Monthly Notices* for 1869, April 9 (vol. xxix. page 259), in which he shows how this varies for different observers.

Recently I have made a fresh determination of the apparent diameter of the Moon as resulting from the altazimuth observations from 1862 to 1878. This too varies very much for different observers; but the mean result seems to show that the correction to the semi-diameter adopted by Hansen, as used in the *Greenwich Observations* since 1863, is somewhat too large, both in azimuth and zenith distance. A change in the former, however, would make but little difference in the mean result; because the number of observations of the first and second limbs respectively in each year is very nearly the same. The semi-diameter used in zenith distance is more effective in the mean result; since, on an average, about three times as many lower as upper limbs of the Moon are observed. But then the mean

* The results for the first three quarters of the year (all now reduced) are as follows:—

		No. of Obs.	Mean Error in Longitude.
			$''$
1879	January to March	28	$+8\cdot25$
,,	April to June	42	$+8\cdot69$
,,	July to September	47	$+9\cdot48$

error of zenith distance produces a comparatively small effect on the mean error of longitude.

Blackheath,
1879, *Nov.* 24.

Addendum.

By the request of Mr. Neison, I have calculated the mean error in longitude for 1878 in two divisions—up to June 1 and after that date. Before June 1 there were 61 observations made with the altazimuth, of which the resulting mean error of longitude is $+7''\cdot54$; after June 1 there were 100 observations, and the corresponding resulting mean error is $+7''\cdot44$. So that the observations in the earlier and later part of that year give results almost identical with each other.

A question having been raised as to how far the changes in the mean error may have been affected by changes in the observers, and in their personality in observing, I have also put together the results of the observations of Mr. Criswick alone, who has been for several years the standard observer at the Royal Observatory, and whose observations extend regularly through the whole of the period during which Hansen's Tables have been used. The following are the resulting mean errors of longitude from the Transit-Circle observations made by him on the separate years specified:—

Year.	No. of Observations.	Mean Error of Longitude by Transit-Circle.
		$''$
1862	15	$-2\cdot70$
1866	21	$+2\cdot94$
1870	21	$+4\cdot61$
1874	25	$+8\cdot80$
1878	18	$+7\cdot74$

1879, *Dec.* 22.

Note on the North Polar Distances of the Greenwich Seven-Year Catalogue for 1860. By A. M. W. Downing.

In a communication to the Society at the November Meeting Mr. Stone has given the results of a comparison between the North Polar Distances of his great Catalogue and those of the *Nautical Almanac*; and has deduced the remarkable result that the adopted refractions are too large for the observations made at the Cape during the dry season in November, December, and January, and too small for the observations made at the opposite season of the year. I have examined my comparison of the

Cape and Greenwich Catalogues for 1860, published in the *Monthly Notices* for 1878, December, in order to ascertain whether any similar effect of the season of the year on the refraction can be detected in the Greenwich observations. For this purpose I have arranged in order of R.A. the stars used in the comparison which are situated between N.P.D. 110° and the horizon of Greenwich, as it is reasonable to suppose that for these stars (which pass the meridian of the Cape within 15° of the zenith) any effect that can be traced to refraction is due to the Greenwich, rather than to the Cape observations.

The quantity $-0''{\cdot}18$ has been applied to the Greenwich places of all the stars used, this being the systematic difference of the Catalogues between the limits of N.P.D. under consideration.

The result then is :—

	h h	h h	h h	h h
Right Ascension	0—6	6—12	12—18	18—24
	"	"	"	"
Corr. to Greenwich	−0·10	−0·04	+0·26	−0·11

The only one of these mean differences worth attention is probably that for 12^h–18^h, and it appears to show that (if the discordance may be considered as due to refraction), from error in temperature correction, or other causes, the refractions used in the reduction of the Greenwich observations are relatively too small during the months of May, June, and July. It will be remarked that the discordance at the opposite season, included within the limits of R.A. 0^h–6^h, is so small that it may probably be considered as merely accidental.

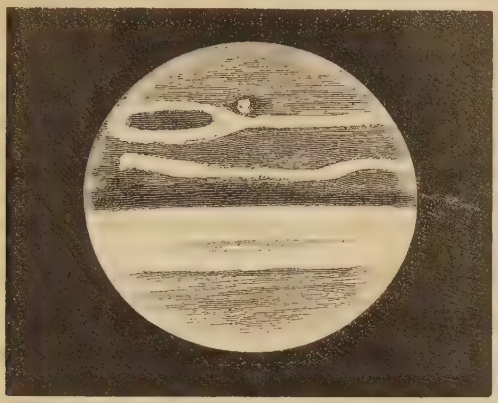
Note on two Sketches of Jupiter.

By Captain William Noble.

The sketches of *Jupiter* which I herewith present to the Society, were made on the nights of October 4 and October 18 of the present year, and to a great extent explain themselves. They show the very remarkable red spot which has attracted the attention of every observer during the present opposition, and the great dark equatoreal belt to the north of it. They further exhibit the curious assimilation of the contour of the surroundings of the red spot to the outline of the spot itself; an assimilation which would seem to indicate that the convulsion to which this most noteworthy marking can only be referable must be of the most stupendous kind.

One point, however, to which I would particularly invite attention is in connection with the white spot which was visible S.F. the red marking on October 4. In a paper read before the Society by Mr. Brett, in June 1876, he directed our notice to the fact that a bright spot sometimes casts a shadow. Now on the night

on which my sketch was made the spot of which I am speaking not only cast *a* shadow (assuming these markings to be such), but *shadows*, as two (as shown in my drawing) were visible, one on



Jupiter, 1879, Oct. 4. $10^h\ 40^m$ G.M.T.
4·2-inch Ross Achromatic; 61 inches focus; power, 255.

its preceding and the other on its following edge. I confess that no immediate explanation of this occurs to me. In the relative position occupied by *Jupiter* and the Sun at the epoch of my drawing, if we assume the white spot to have consisted of a globular mass of vapour raised high above the surrounding surface of the planet, it is quite evident that it would cast a well-marked shadow behind it. Upon what principle, however, it should simultaneously throw another one in front of it I am wholly at a loss to determine. It may be worthy of remark that the light interval separating the northern and southern equatoreal belts, which at the epochs of my sketches merely appeared as a sinuous but unbroken line on that part of *Jupiter's* disk more immediately north of the red spot, on the opposite side of the planet presented a much more complicated form. It altered in this respect between September and October.

Forest Lodge, Maresfield,
Uckfield, Sussex,
1879, *November* 12.

Note on the Spectrum of the Red Spot on Jupiter.

By Lord Lindsay.

Spectrum of *Jupiter* in Grubb spectroscope on 15-inch. Lowest power best. Probably 100 solar lines seen. The 3 magnesium lines beautifully separated. Slit at right angles to belts. The red equatoreal belt seen as a dark band running through the

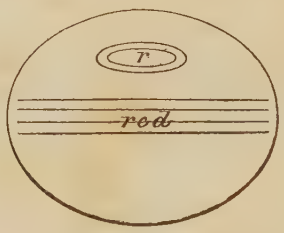
spectrum from extreme red end to between F and G, limit about $38^{r}{\cdot}31 = 453^{mmm}$ wave-length, much the darkest from about *b* to F, somewhat darkest of all nearer F.*

Examined satellites 1, 2, and 3; could not make out any lines. The spectrum of 3, when much broadened by a cylindrical lens, was repeatedly seen to be traversed from end to end by a dark band, as if it had belts.

Jupiter.—Slit parallel to belts. Only one very small spot showed the obscuration described above. On examining *Jupiter* with the low power on the micrometer, it was found that the obscuration in this case arose from a detached red spot in the southern hemisphere. The absorption seemed to be more restricted to the region of spectrum near *b* and F than in previous observation.

With the prism of the Vogel spectroscope held in front of eye-piece of the micrometer, obscuration-lines were very distinctly seen when refraction angle of prism was parallel to axis of *Jupiter*. In other positions they were overwhelmed by the light from the remainder of the disk.

The general appearance of *Jupiter* was very roughly somewhat like this at 13^{h}:



The upper red spot was surrounded by a very narrow white margin.

Observers, R. Copeland and J. G. Lohse.

A few weeks ago the Rev. James Virtue, of Dumfries, was so kind as to point out that he saw the large detached red spot on *Jupiter* with the Dun Echt Refractor on the night of June 26, 1878. The date is confirmed by the Diary at Dun Echt, although the observation is not recorded.

The visitor describes the "cloud" as seen "on the upper right quarter of the disk."

1879, *Sept.* 26.

* This phenomenon is fully described by Vogel in his *Untersuchungen über die Spectra der Planeten*, pp. 25, *et seq.*

The Nebula in the Pleiades. By Maxwell Hall, Esq.

It is now about three years since I called attention to this nebula in the pages of *Nature*. At that time it had not been seen through Lord Rosse's telescopes, and as it was very distinct in my own 4-inch Refractor aided by splendid skies, I sought for an explanation.

One was given by the Editor, who said that the light from *Merope* would extinguish the nebula in large telescopes, if I understand him aright.

But as the ratio of the light of the star to that of the nebula remains the same whatever the aperture may be, this explanation did not seem very conclusive; and indeed the nebula has been seen repeatedly since that time at the Birr Castle Observatory.

Again, it has been seen through Mr. Newall's 26-inch Refractor; and his verbal description of the nebula corresponded so closely to what I have always seen in Jamaica, that my sketch made in March 1877, after about a year's attention to the nebula, may prove valuable.

When the annexed drawing of the *Pleiades* was made, the stars with Flamstead's numbers from 16 to 28 were taken from the British Association Catalogue and brought up to date; these stars formed the groundwork, and the chart was filled in from observation at the telescope by the eye alone, so that the drawing is a mere sketch of that group of stars. But *the wreathing of the stars* is well brought out, and great care was taken with the stars in the neighbourhood of the nebula. The limits of the nebula were obtained by moving the telescope rapidly in order to obtain contrast, and great pains were taken in the shading of the drawing of the nebula in order to show the contrast between light and darkness. A power of 100 was generally employed.

It was with great surprise that I saw very recently the drawing of the nebula in Dr. Engelmann's chart of the *Pleiades* (see p. 304, vol. i., *Abhandlungen von F. W. Bessel*, herausgegeben von R. Engelmann, Leipzig, 1875), where it is represented as a very small circular patch of light in no way connected with *Merope*, and situated about 11′ from that star along the axis of figure as represented in my drawing. It is perhaps as well to add that this nebula was discovered by Tempel in 1859, twenty years after the first series of observations made by Bessel.

Tempel also employed a 4-inch telescope, but he found it much smaller than my drawing; it appeared to him of an elliptical form, the greatest and least diameters being about 35′ and 20′; while my estimated diameters are 45′ and 30′.

For the evidence respecting the variability of the light of this nebula I must refer to an excellent summary given by Mr. Webb, in the *Intellectual Observer*, vol. iv., p. 449; where we read, "Schönfeld at Mannheim doubts the fact of variation, and he thinks that this and other suspected nebulæ, being very feeble, large, and diffused, are influenced in visibility by magnifying

power, varying transparency of the air, and practice of the eye, so that aperture is less concerned in their case than in that of minute stars. Auwers, of Göttingen, argues on the same side. It has often, this observer says, been remarked—Encke's comet being an instance of it—that large, ill-defined, faint objects are best seen with small instruments."

Again, in the third edition of Mr. Chambers' *Descriptive Astronomy*, the following remarks were taken from the *Ast. Nach.*, vol. 86, No. 2045 :—"Schiaparelli, at Milan, trying a new telescope on February 25, 1875, saw this nebula very clearly, and was much surprised at its size. He noted it to extend from the star *Merope*, beyond *Electra* and as far as *Celæno*."

That is to say, he saw it extending in a direction at right-angles to the axis of my figure, seen the year following his observation, though not drawn until later.

It is to be hoped that further observations will be made of this most interesting nebula by possessors of telescopes with both large and small apertures; indeed, there seems to be quite a new field of research opened out for smaller telescopes. At the present moment I am inclined to think that the state of the air has great effect upon the visibility of this nebula and similar objects; for, with my four-inch Refractor on the mountains of Jamaica, I have seen the third or *gauze* ring of *Saturn* as clearly and as fully extended as in the drawings taken with the largest and most perfect instruments.

Discovery of a Gaseous Nebula in Cygnus.

By the Rev. T. W. Webb, F.R.A.S.

On the night of November 14, as I was sweeping in *Cygnus* with a power of probably about 50 on my 9·38-inch silvered mirror, by With, I came across an object resembling a bluish 9-magnitude star, which, however, on closer examination, did not entirely resemble other stars of that size, and which was soon proved by change of eye-piece to be of an entirely different nature. Under powers of 212, 375, and 450 it appeared as a nebulous disk, surrounded perhaps by a feeble glow, and about 4″ in diameter. It was readily identified by Lord Lindsay and Mr. Knott as No. 4004 in Argelander, +41°, with a place for 1880 of R.A. $21^h\ 2^m\ 31^s$, D.N. 41° 45′·3, and both observers recognised its monochromatic light.

Through the kindness of Dr. Copeland, by whom it has been carefully examined, under peculiarly favourable circumstances, at Lord Lindsay's Observatory, I am enabled to add the following interesting particulars.

It is not round, and has a sharp nucleus near the *n.p.* edge, with a faint effusion of light in the opposite direction. The value of three very measurable bright lines was given respectively in two

sets as 500·1, 495·7, 487·0, and 500·1, 495·6, 486·0, and these accord so closely with the results deduced by D'Arrest, 500·4, 495·7, and 486·1, for lines of this nature, that there can be no question as to the character of the object. The relative strength of the lines appeared to Dr. Copeland to be about 8, 5, and 1, reckoned from the least refrangible end.

Hardwick Vicarage,
Dec. 1, 1879.

Note on the Gaseous Nebula in Cygnus. By G. Knott, Esq.

In a letter dated November 22, the Rev. T. W. Webb called my attention to a small object in *Cygnus* which he suspected might prove to be a gaseous nebula, a suspicion which I was able to confirm by observation on the 25th, when, with a McClean Star Spectroscope on my $7\frac{1}{3}$-inch Refractor, I found its spectrum to consist apparently of one bright line of considerable intensity. The nebula is found in the *Bonner Durchmusterung*, where it is Zone +41° No. 4004, and with a small aperture and low magnifying power has the appearance of a hazy star of the 8·5 magnitude, which is the magnitude assigned by Argelander. With the full aperture it presents the appearance of a bright bluish white nebulosity slightly elongated *n.p. s.f.*, and I have the impression that it is brightest at its north preceding extremity.

Knowles Lodge, Cuckfield,
Dec. 11, 1879.

Note on the Rev. T. W. Webb's New Nebula.
By Lord Lindsay.

At 6 P.M. on November 22 Rev. Mr. Webb's planetary nebula was seen approximately monochromatic with a prism in front of the micrometer eye-piece. This observation was confirmed on the following evening, and late in the night Mr. Lohse saw a spectrum of three bright lines with the Grubb spectroscope.

On November 26, with the same spectroscope, the lines were found to have the following wave-lengths:—

	1	2	3	
	500·1	495·7	487·0	Observer, R. Copeland.
	500·1	495·6	486·0	,, J. G. Lohse.
Brightness	8	5	1	

The comparison spectrum was a hydrogen tube of Professor Piazzi Smyth's construction.

The nebula under a power of 307 shows a sharp nucleus near the *n.p.* edge, while the opposite side fades away like a very short tail or wisp.

The Nebula in Cygnus. By Prof. Winnecke.

(*Extracts from letters to Lord Lindsay.*)

I beg to express my best thanks for the kind announcement of the interesting discovery of Mr. Webb.

November 28, the Moon being full, I could look at the new nebula. With the Orbitsweeper (aperture 6 Paris inches, power 260) it looked like a star of the 8th magnitude out of focus, and the object-glass not centred. It was oblong in the direction 136°·1, with a lucid point like a star 10–11 mag. in the preceding part; greatest diameter, 5″·5; least, 4″·9. The nearest star which I could see in the bright moonlight was 11 mag. By four measures I found :—

Neb. – ∗ 11 mag.

Dist. = 135″·7. Pos. angle = 282°·0.

On applying a stellar spectroscope the spectrum appeared to be continuous, but rather knotty (perhaps bright lines?). It was about 3′ long, and quite different from the nearly monochromatic gaseous spectrum of H. iv. 18, which was looked at immediately afterwards.

I should feel much obliged if you would communicate these remarks to the next meeting of the Royal Astronomical Society in London.

Strasburg, 1879, *Nov.* 30.

I wrote to you on Mr. Webb's new planetary nebula, on November 30. Afterwards I saw it (December 2), but the night was very foggy, so that the small star near it was not visible. The nebula had the appearance of a very small comet, the nucleus being near the preceding edge; it was elongated in $p = 134°{\cdot}3$ (1), and with the wire-micrometer the length of the major axis was found (with power, 365) $= 6″{\cdot}2$ (1). On applying the small Merz star spectroscope, I was very much surprised to find the light nearly monochromatic! Yesterday evening it was very clear, and I could look, for the first time, at the nebula in a dark sky. The spectrum was decidedly of the gaseous character; the first very bright image of the nebula was crossed by a long faint ray, which is to be ascribed, probably, to the spectrum of the small nucleus, which was afterwards very prominent with power 365. The small Merz star spectroscope (without slit) showed yesterday the spectrum of the star 9·1 mag. near it (B.D., 41°, No. 4001) about 10′ long. I have therefore no doubt that the new nebula is a gas nebula; still I can by no means understand the observation of November 28; perhaps a clue may be found in the circumstance that the nebula was not

visible that day in the finder, the moon being too bright. Still the clock was driving perfectly the Orbitsweeper, as it did yesterday evening with $-13°$ C. I should be very glad if another astronomer had observed the nebula with a spectroscope at the same time. The position of the small star preceding the nebula was found :—

Dec. 7 Dist. = 136″·9 (4) Pos. angle = 281°·9 (4)

Pos. angle of elongation of the nebula p = 132°·3 (2)

Length of major axis = 5″·7 (1)

Strasburg, 1879, *Dec.* 8.

Observation of General Catalogue (*Supplement*) *No.* 6,000.

By Lord Lindsay.

This object is marked " Planetary ? " in the Harvard Zones (*Annals*, vol. i. p. 67). Assuming that this query indicated that the object was seen as a planetary nebula by W. C. Bond, D'Arrest observed it at Copenhagen, but found it quite stellar in appearance. At the suggestion of Mr. Dreyer, it was observed prismatically at Dun Echt on December 10 by Ralph Copeland. The spectrum is quite continuous and offers no peculiarity ; the object is therefore not a nebula at all. It is identical with D.M.+0° No. 4741, 8·8 mag.

Note on Mimas and Hyperion. By A. A. Common, Esq.

Attempts were made in 1877 and 1878, with an 18-inch Reflector, to observe *Mimas*, but without success ; on two nights it was thought to have been seen. *Hyperion* was seen on several nights.

With the 36-inch telescope *Mimas* can be fairly well seen when some 3″ or 4″ from end of ring ; one attempt to follow it up to conjunction has failed, but under better circumstances it may perhaps be done. The more certain observations (which seem to indicate that the Ephemeris published by Mr. Marth in the *Ast. Nach.* No. 2273 is some one and a half or two hours late) are given below, with some measures of *Hyperion*.

Moonlight that had no effect on *Mimas* utterly obliterated *Hyperion*. This was particularly noticed on the night of November 22.

Sept. 25. At 9.15 G.M.T. *Mimas* was seen E. and expected to be going out from ring; it was, however, found to be approaching, and at $10^h\ 50^m$ appeared to be much closer. The *n.f.* conjunction was estimated to take place at $11^h\ 40^m$, as it could not be followed after $10^h\ 50^m$.

October 10. At $10^h\ 0^m$ to $10^h\ 15^m$ *Mimas* was seen E. a little S. of end of ring; a deposit of dew on the small mirror preventing further observation.

Nov. 13. At $9^h\ 15^m$ *Mimas* was seen E. and apparently half-way between *Tethys* and end of ring. At $9^h\ 24^m$ it was well seen below a line joining *Tethys* and end of ring.

Nov. 22. At $8^h\ 44^m\ 40^s$ *Mimas* was seen W., estimated to be exactly under *Tethys* and $5''{\cdot}96$ from end of ring. At $9^h\ 25^m$ *Tethys* had moved to a place about half-way between *Mimas* and end of ring; and at $9^h\ 40^m$ *Tethys* was nearly up to conjunction and *Mimas* some $3''$ or $4''$ distant from ring.

HYPERION 1879.

	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Oct. 21	10 58	271 46	252·77	2	This was measured, as decided motion was observed from a star near.
	11 0	102 45	87·18	1	Noted as something like *Hyperion*.
Nov. 11	8 22	270 54		2	Night fine, but windy.
	8 23	270 48		2	
	8 27		253·55	2	
	8 32	270 40		2	
	10 16	271 14		2	
Nov. 13	7 20	267 8		1	Fine night.
	7 23 30		203·3	1	
	7 25 5	267 1		1	
	9 7	268 25		3	
	9 8 15	268 13		2	
	9 10 30	268 7		2	
Nov. 15	8 26	256 44	102·52	1	Very fine night.
	8 31	258 15	103·62	2	
	8 32	256 16		2	
	8 44	257 42		3	
	8 49		99·38	4	
	8 50	259 28		4	
	8 49 30		99·85	4	
	10 34	252 50		1	
	10 36 30		92·47	1	

	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Nov. 15	10 40		95·45	2	
Nov. 18	8 9 5	105 7	108·49	2	Night very fine, with heavy dew.
	8 11 50	103 48		3	
	8 13 25	103 33		4	
	8 15		106·28	2	
	8 43 50	102 24	110·99	3	
	8 47 15	103 33	109·9	3	

Nov. 1879.

Observations of the Satellites of Mars. By A. A. Common, Esq.

The following observations of the satellites of *Mars* were made by me at Ealing, near London, with an Equatoreal Newtonian Reflector of 36 inches aperture. In all cases the full aperture was used with powers of 220, 240, or 380. The great disparity in light between the objects to be measured necessitated some modification of the ordinary micrometer which it would perhaps be better to describe.

Instead of using a bar in the field, behind which the planet could be placed by moving the whole micrometer, as was done by me at the last opposition, this was done:—The spider webs were taken out of an ordinary double parallel-wire micrometer and the springs taken away from one frame. This frame was then free to slip easily to and fro, and as far in as the nut was adjusted to. Attached to this frame, somewhere near where the wire would be, was a light arm, carrying at the end a small disk of steel just large enough to hide the planet, and so placed as to slide central over and along the position wires up to the intersection of these by the fixed wire supplied to replace the wire taken from the frame spoken of. These position wires were of silk fibre, two in number, and placed at a distance apart equal to about 12″ of arc. The other frame carried a similar wire, and was movable in the ordinary way. The idea with this arrangement was to place the intersection of the fixed wire with the position wires central on the planet and then bring up the steel disk to hide it, adjust the position wires at an equal distance on each side of the satellite, then bring down the movable wire, and so get a measure of position and distance at one operation. But in practice it was found that the fixed wire interfered somewhat with the proper placing of the others on the planet, and it was not always done in this way.

Measuring positions in this way with double wires, where the objects are comparatively close (considering the width of the parallel wires), although suggested or recommended to be done by Professor Hall, in his account of the discovery of the satellites,

seems to me to be inferior to the use of one wire, or of three wires —the two outer ones being placed so as to cut off very small segments of the planet, the central one bisecting the satellite, and the measurements being made in pairs by rotating the position-circle through 180°, unless the middle wire could be placed exactly central—thus getting rid of the uncertainty that exists in properly placing the satellite with respect to the two wires.

Better results may be obtained by using a piece of dark glass (in place of the steel disk) of the proper shade to diminish the light of the planet and allow the wires to be seen through. A micrometer fitted in this way, with the glass behind the wires, answers very well indeed here and on *Saturn*. It was not used in these measures.

As to the brightness of the satellites about opposition (November 2), *Deimos* was considered to be about equal to *Enceladus*; and *Phobos* a little brighter than *Tethys*, not taking into account the glare, but estimating by imagining them isolated. The character of the light was, however, different, being sparkling and starlike, not of the quiet aspect of any of *Saturn's* satellites. This may be due to the absence of any apparent disk, or to contrast with the dull brightness of *Mars*. The colour of *Deimos* was slightly bluish, *Phobos* quite white. At the last opposition *Deimos*, the only satellite well seen, was noted as of a similar colour to *Mars* with a higher power on a smaller telescope.

On November 2 the Moon was very bright, but it had no appreciable ill effect on the visibility of the satellites; if anything, it seemed an advantage.

A weight is attached to each measure on a scale extending from 1 to 5.

All measures of position are subject to the uncertainty of estimation spoken of, but are of course independent of each other, and, with the exception of some few distances, none have been rejected.

The apparent movement of the stars near *Mars* was noted, but nothing like a third satellite was seen.

Deimos.

Date. 1879	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Sept. 21	15 3	240 36		1	A fine night; Satellite seen at once.
	15 5	240 0		1	
	15 19	235 45		1	
	15 37	237 0		2	
	15 41	237 35		3	
	15 43	238 25		1	
	15 45	237 31		3	
	15 48	236 43		3	
	16 17	234 45		2	

Date. 1879	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Sept. 25	11 54	232 53		1	Rather misty night.
	12 0	234 4		1	
	12 2	233 1		1	
	12 5	233 55		1	
Oct. 15	11 53	249 20		1	Night very windy.
	11 58	247 30		1	
	12 2	246 58		2	
	12 3	247 33		2	
	12 5	247 10		2	
	12 7	245 35		2	
	12 20	245 32		2	
	12 22	243 14		2	
	12 27	244 40		3	
	12 36	245 30		2	
	12 55	243 50		2	
21	9 15	52 20		1	
	9 25		48·8	1	From limb.
	9 34 30	53 36		1	A star brighter than satellite about 20″ beyond. A beautiful night.
	9 36	52 8		2	
	9 37	53 6		3	
	10 16 30	49 22		3	
	10 23 30	49 56		2	
	10 25	49 22		2	
	10 27		45·21	1	From limb.
	10 32	49 41		1	
	11 24	44 31		2	Satellite now faint.
	11 27 30	47 30		2	
	11 30 30	44 30		2	
	11 31 30	46 4		2	
	11 37	46 37		2	
Nov. 2	8 9	231 22		1	Windy night.
	8 11		67·54	2	Definition very fine.
	8 15	233 20		2	Distances taken from centre of disk of planet.
	8 16	232 40	67·55	2	
	8 20	232 25		2	
	8 52	229 53		2	
	8 56	229 14		2	
	8 58	228 55		3	
	8 59	229 34		4	

Date. 1879	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Nov. 2	9 6 30	230 15		3	
	9 8	230 4		3	
	9 10		66·09	3	
	9 18		63·89	3	
	9 19 30	230 8		3	
	10 19		61·39	3	Just visible with Mars in field.
	10 20		61·70	3	
	10 21	227 45		4	
	10 22 30	227 30		4	
5	8 44 30	62 26	56·83	2	Rather hazy.
	8 47 30	61 37	54·32	3	
	8 56	60 21	54·17	3	
	9 4	59 42	57·24	3	
	9 10	60 56		3	
11	8 43 30	210 49		3	Fine night.
	8 48	212 14		2	
	8 52 30	212 5		2	
	8 54 20		36·73	2	
	8 57		39·40	1	
15	9 31	73 2		3	Not at all easy to measure.
	9 40	72 36		3	
	9 42		39·85	1	

Phobos.

Nov. 2	8 31	220 58		1	First seen.
	11 2	55 30		2	
	11 7	57 30		1	Bad seeing.
	11 20	51 1	27·16	3	
5	8 11	51 20	25·12	2	Not very clear night.
	8 15	51 58		2	
	8 19 30	48 40	25·27	2	
	8 23	49 15	26·69	2	
	8 26	50 8		1	
	8 27 30	48 4		3	
11	9 4 30	62 24		2	Fine night, but windy; satellite very bright.
	9 6	60 25		3	
	9 17 45	55 12		4	

Date. 1879	G.M.T. h m s	Pos. ° ′	Dist. ″	Value.	Remarks.
Nov. 11	9 20	55 8		3	
	9 22	56 25		2	Under 1 wire.
	9 25	52 10		2	Over 1 wire.
	9 26 15	53 18		3	
	9 28	53 2		4	
	9 49	52 19			
	9 52		26·69	2	
	9 52 30		26·84	3	
	9 59 30	47 19		3	
	10 1	48 14		4	
	10 3	48 16		2	
	10 6 20	46 47		4	
13	7 44 10	51 25		2	
	7 46	49 30		2	
	7 47	50 5		2	
	7 48 30	51 27		1	
	7 51 40	50 19		3	
	10 55				Seen *s.p.* very faint.
15	9 8 15	235 59		5	Satellite seen with planet; very fine night.
	9 10 30		26·60	5	
	9 12	236 35		5	
	9 13 45	235 28	25·42	4	
	9 15 30	236 4		5	
	9 46	228 46		3	
	9 47 30		23·86	3	
	9 49 15	229 50		3	
	9 52	228 55		4	

November 1879.

New Double Stars. By S. W. Burnham, Esq.

Since the preparation of my last Catalogue and measures (*Memoirs of the Royal Astronomical Society*, vol. xliv.) the work has been continued at the Dearborn Observatory whenever circumstances permitted; and I desire, in advance of the publication of another Catalogue, to call attention to some of the double stars discovered during the present year, in order to give

observers who have the necessary instruments an early opportunity of measuring them.

The following, selected from a list of considerable length, are all naked-eye stars, and most of them important objects. I give the mean result of my measures, usually about three nights for each star.

No.	Star.	Pos. °	Dist. ″	Mags.	Epoch.	
1	β Scorpii	89·4	0·79	2 ...10	1879·53	A and B.
2	31 Virginis	28·7	3·56	6 ...12	·33	
3	48 Virginis	229·4	0·48	6 ... 6	·40	
4	86 Virginis	298·4	1·61	6 ...10·5	·37	A and B.
		274·2	1·72	11·5...13	·40	C and D.
		164·7	26·94	...	·33	A and C.
5	46 Eridani	57·0	1·47	6 ...10·5	·05	
6	26 Draconis	149·1	1·36	5·5...10·5	·28	
7	52 Hydræ	276·8	4·00	5 ...11	·42	
8	54 Herculis	175·4	2·56	5 ...12·5	·37	
9	η Cygni	209·0	7·20	4·5...13	·44	
10	65 Aurigæ	8·3	10·36	5 ...12·5	·00	A and B.
		26·8	36·10	...13	·00	A and C.
11	B.A.C. 4389	109·2	2·68	6 ...12	·28	
12	B.A.C. 5248	152·0	1·31	5 ...11	·28	
13	B.A.C. 6966	153·6	0·80	6 ...10	·56	
14	Rad. 6180	244·2	0·88	6·5... 8·5	·46	
15	Virginis 550	81·2	0·47	6 ... 6·5	·39	A and B.
		156·5	23·88	12·5	·37	AB and C.

1. *β Scorpii.*—This star has been known as a wide double for more than a century. After measuring the close pair of *ν Scorpii*, and while the highest micrometer eye-piece (900) was attached, I examined *β*. The conditions were very favourable for a star so far south, and the duplicity of the principal star was at once detected. I have only been able to get three measures of it during the present season. It is a very difficult pair, and far beyond any close pair hitherto discovered in the inequality of the components. I know of nothing among the large stars that is comparable with it, except *η Piscium*, discovered with this instrument last year. That is generally similar, but the principal star is of the fourth magnitude. Doubles of this description are the best possible tests for the quality of a telescope. In the southern hemisphere a Clark Refractor of 12 inches would probably show it. No second-class instrument, however large, will do it satisfactorily, if at all. There is not much doubt of this proving a physical system.

2. 31 *Virginis.*—This is comparatively an easy pair, and ought not to have been missed by Struve and others.

3. 48 *Virginis.*—A fine close pair, and well separated with the power used in measuring. The components seem to be exactly equal in magnitude.

4. 86 *Virginis.*—(A and C = Σ 1780 *rej.*) This star with a distant faint companion was noted by Struve, and inserted in his first Catalogue, but rejected as too wide and unimportant in the *Mensuræ Micrometricæ*. The 18½-inch shows both of these stars double. The attendant to the large star is very easily seen, and I think not beyond the reach of my 6-inch, but the companion to Struve's star is very difficult, and requires a large aperture. In fact, I did not detect it until after measuring AB two or three times. The components taken together form the closest quadruple system known. Sir John Herschel observed the Struve stars with the 20-foot Reflector at the Cape of Good Hope in 1836, and found the angle, 160°·3, but missed the close stars, as in many other similar instances.

5. 46 *Eridani.*—A fine easy pair.

6. 26 *Draconis.*—Very much like the last in distance and magnitudes.

7. 52 *Hydræ.*—Companion smaller than the two preceding, but more distant. This was found independently with the 6-inch, on Mount Hamilton, and very easily seen.

8. 54 *Herculis.*—The companion is quite faint, and requires a larger aperture than the three preceding pairs.

9. *η Cygni.*—Herschel, with the 20-foot, Reflector noted two distant stars which he called 18 magnitude (= H. 1455). His estimated places are—

	°	″
A and C	170 ±	: 20 ±
A and D	332·0	: 30 ±

They are very much brighter than the new star, and probably have, at least, twice the light. I have called them each 11·5 magnitude. My measures give the following places:—

	°	″	
A and D	P = 325·3	D = 46·17	1879·47
A and C	170·0	49·52	1879·47

The star in the *n.p.* quadrant is really the nearest. The new star is a very minute point, but has been readily seen by Edgecomb with his 9·4-inch Clark Refractor without any intimation of the direction from the principal star.

11. B.A.C. 4389.—The place of this star is, R.A. $13^h\ 0^m$: $+45°\ 54'$. It is a fine unequal pair.

12. B.A.C. 5248.—The place is, R.A. $15^h\ 45^m$: $+55°\ 45'$.

13. B.A.C. 6966.—Both close and unequal. R.A. $20^h\ 10^m$: $+25°\ 14'$.

14. *Radcliffe* 6180.—Heis gives this as a naked-eye star. R.A. $23^h\ 42^m$: $+46°\ 10'$.

15. *Virginis* 550.—A variable star discovered by Schmidt in 1866, and supposed to be variable from 5 to 8 magnitude. It is a fine close pair with a minute distant companion. This is B.A.C. 4531, R.A. $13^h\ 28^m$: $-12°\ 36'$.

In addition to the foregoing, I have divided the principal components of the following known pairs :—

Σ 157	Σ 888
Σ 258	Σ 2005 *rej.*
Σ 439	S. 752
Σ 707	H. 2661

Chicago, Nov. 15, 1879.

Observations of the Outer Satellite of Mars made at Dun Echt Observatory. By Lord Lindsay.

Date. 1879.	Dun Echt Mean Time.	Pos. Angle.	Cor. for Refraction and Phase.	Dist.	Cor. for Refraction and Phase.	Comparisons.	Observer.
	h m	°	°	″	″		
Nov. 12	11 20·1	226·37	−·01	62·33	+·02	3	R. C.
,,	11 44·7	228·02	−·01	59·72	+·02	1	,,
,,	12 16·1	223·46	−·01	59·44	+·02	3	,,
,,	12 34·8	222·92	−·01	59·07	+·02	1	,,
Nov. 14	11 24·0	40·77	·00	43·48	+·02	1	,,
,,	11 33·2	39·57	·00	46·78	+·02	1	,,
,,	11 53·4	38·27	·00	47·46	+·02	1	,,
Nov. 17	10 34·6	233·77	−·01	64·14	·00	2	,,
,,	10 46·3	233·16	−·01	64·78	·00	2	,,
,,	10 54·6	232·57	−·01	62·57	·00	2	,,
,,	12 9·1	229·77	−·02	61·65	+·01	1	J. G. L.
,,	12 23·2	229·47	−·02	64·07	+·01	1	,,
,,	12 33·1	227·70	−·02	61·35	+·01	1	,,
,,	12 47·7	227·33	−·02	62·06	+·01	1	,,
* ,,	13 13·7	225·90	−·02	57·13	+·01	1	,,
* ,,	13 33·7	225·50	−·02	63·58	+·01	1	,,

* The last two observations are probably vitiated from the fact of *Deimos* passing very close to a star equal to itself in brightness. In fact, during these two observations they appeared as a single object, the centre of which may not have coincided with that of the satellite.

The observations were made with a power of 229 on the Refractor of 15·06 inches aperture. The field of the eye-piece was contracted to 2′ by a diaphragm in order that *Mars* might be shut out from view by moving the slipping piece while the illuminated wire was placed on the satellite.

It may be remarked that when the sky was quite clear the micrometer wires could not be seen without artificial illumination, when *Mars* was out of the field. The satellite was never seen together with more than the diffracted edge of *Mars*.

The initials are those of the observers, R. Copeland and J. G. Lohse.

Observations of Mr. Baxendell's Star in Canis Minor. By Lord Lindsay.

Mr. Lohse has determined the place as follows:—

879.	Bax. ✱ − B.W. Δα	Δδ	α 1879·0.	δ 1879·0.	Weight.	Comparison-stars.
	s	′ ″	h m s	° ′ ″		
v. 27	− 4·29	−2 57·2	7 34 45·62	+8 39 40·2	3	B.W. vii., 1029
	+31·90	− 51·2	7 34 45·69	+8 39 37·8	1	B.W. vii., 1014
			7 34 45·67	+8 39 39·6		

Adopted places of Comparison-stars for 1879·0.

	δ	Reduction.	δ	Reduction.
	h m s	s	° ′ ″	″
W. vii., 1029	7 34 50·91	+4·89	+8 42 37·5	−6·4
W. vii., 1014	7 34 14·78	+4·90	+8 40 28·9	−6·2

Examined with the spectroscope, the star shows no peculiarity. No particular colour predominating, although to the eye the colour is sensibly faint red or purple. Comparisons of brightness from November 27 to December 8 indicated a decrease of half a magnitude; but on December 10, under very favourable circumstances, the star appeared about as bright as on November 27, say 8·9 mag. of Argelander's scale.

Note on a New Star in Canis Minor. By G. Knott, Esq.

A circular was issued from Lord Lindsay's Observatory, Dun Echt, on November 25, announcing the discovery by Mr. Baxendell of a new orange-coloured star of the 8·8 magnitude in *Canis Minor*, near the star B. D. Zone +8° No. 1848. My first view

of the star was obtained on December 1, when it appeared to be some half magnitude less than its neighbour 1848, and about equal to a star some little distance preceding, B. D. Zone +8° No. 1846, the magnitudes of which two stars I determined on December 6 and 10 to be 8·3 and 8·9 respectively. On December 2 I thought the star to be perhaps rather brighter, and on the 6th, 10th, and 11th to be perhaps rather fainter than 1846; but its tint, which is a decided ruddy yellow or orange, combined with varying atmospheric circumstances, may have affected the estimates. On December 6 I determined its differential coordinates with respect to 1848 to be

$$\Delta\alpha = -4^{s}\cdot35, \quad \Delta\delta = -3'\cdot0,$$

which would give for its approximate mean place for 1880·0

$$\alpha = 7^{h}\ 34^{m}\ 49^{s}, \quad \delta = +8^{\circ}\ 39'\cdot5.$$

Knowles Lodge, Cuckfield,
Dec. 12, 1879.

ERRATUM.

P. 5, last line should be

$$15'\ 33''\cdot37 + 4''\cdot10 \div (1 + 0\cdot70 \times \text{aperture in inches}).$$

viz. the sign of division was omitted.